DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Chemical Industry and European Free Trade

OVER 80% of the chemical industry measured in terms of capital employed has gone on record that, provided it was able to compete on fair terms, it would favour negotiations for a Free Trade Area. This is one of the striking facts quoted in "Britain and Europe"—a study by the *Economist* Intelligence Unit of the effects on British manufacturing industry of a Free Trade Area and the Common Market. Estimates have been made in this survey on the effect of eliminating tariffs not on trade as it is now but as it will be in twelve to fifteen years' time. The authors point out that in a space of less than ten years, the share of petroleum chemicals in the total output of organic chemicals in Britain grew from almost nothing to well over a third. This phenomenal expansion, which completely changed the structure and competitive position of the British chemical industry, was achieved in a period much shorter than the transition period during which the CM and FTA are scheduled to come into effect. Hard upon the heels of the petroleum chemicals comes another possible source of radical changes in the industry: radiation chemistry. Thus the British chemical industry may by 1970 be as different from the industry today as the present state of the industry is from that in 1939. These fascinating possibilities illustrate the peculiar difficulty of attempting any estimate of the performance of the British chemical industry in relation to its competitors in the FTA on the basis of the plants, processes and products of the mid-1950s. They also show that more than anything else the competitiveness of the British chemical firms at the end of the transition period will depend on the range and success of the research that they carry out in the next ten or fifteen years.

With this appraisal goes a warning. In the field of radiation chemistry, British chemical producers will have the benefit of the work already done, and the facilities offered to both large and small firms, by the U.K. Atomic Energy Authority. There seems no reason why Britain should not be able to gain a commanding lead in this field, with far-reaching consequences. But already the German chemical producers are reported to be taking a keener interest in radiation chemistry. It is in this and other fundamental areas of competition—and in the speed with which it can translate its discoveries into commercial production—that the position of the British chemical industry in the FTA will be won or lost. Success depends, possibly to a greater extent than in any other industry, on the supply and calibre of scientists, technologists and chemical engineers—in short on Britain's educational system.

A Self-lining Blast Furnace

THE behaviour of the refractory linings of blast furnaces still leaves much to be desired. Decomposition, abrasion, the growth of "scaffolds" or "arching" may all eventually make it necessary to close down the furnace for lengthy repairs. One possible approach to this question has been suggested by a consideration of the refractory nature of the burden itself, which is granular and flows as if it were a semi-fluid. It seems that the conventional refractory lining could be dispensed with and, in its place, some of the descending charge could be trapped between annular water-cooled baffles fitted at intervals in the shell. The trapped material would form a static automatically self-renewing lining surrounding the slowly descending core of the charge. According to the 1957 edition of BISRA* *Survey* direct observation of accretions on the linings of blown-out furnaces supports the view that such static linings would become dense and impervious, with stable chemical constituents surviving at different heights in the shell. To begin with, a lining of conventional bricks could be built between the shelves with the charge lining progressively taking over as the brickwork wore away, but experience may eventually show even this preliminary brickwork to be unnecessary. This new scheme also permits the use of stack *tuyères* at various levels to inject a mixture of air and fuel for burning away incipient scaffolds. Since the charge lining is continually renewable, no irreparable damage, such as might occur with a conventional refractory lining, could occur. It is thought that this combination of shelves and stack *tuyères* would provide a long-life, problem-free furnace of low capital and operating costs. These proposals are developed in a short 16mm. sound film using a cut-away model furnace to illustrate the argument. The film is freely available on application to the Librarian at BISRA's head office.

* British Iron and Steel Research Association.

When do You Abandon a Research Project?

IT is usual to urge that greater funds should be provided for research. In fact there are two particularly difficult stages in a research project. The first is raising the money, but the next is knowing when to stop. Discussing this problem in a recent paper, J. P. Baxter, Vice-Chancellor of the N.S.W. University of Technology, Australia, urges a good system of financial control allied with regular technical and economic appraisal. To succeed with research Prof. Baxter recommends that top management must accept it, study it and use it in accordance with procedures that are well understood. The cost of a research laboratory should be controlled in two quite distinct ways. Firstly, the laboratory should have an annual budget, approved by the Board, which provides a total sum within which the laboratory must operate. This budget may be divided into broad sections such as research on new products, technical service research for customers, market research, or long range or fundamental research. Each group would be illustrated by the kind of projects which might be carried out, but approval of the budget would not approve individual projects.

This annual budget enables the research director to plan ahead, and gives management a control of total expenditure. Secondly, there should be a system of approval of individual projects. The principle is that each project will receive

approval for a definite amount of expenditure from time to time, and that at each approval there is a formal appraisal of the progress made and of future prospects in the light of that progress. Detailed, written appraisal of the whole project should be prepared each time a financial approval is sought. This ensures that if the realisation of the original objectives becomes less likely owing to problems proving insoluble, or market conditions changing, or some other method of solution appearing, the work can be stopped, and the effort directed to more profitable channels. The paper is reproduced in *Food Technology in Australia*, 1957, p. 527.

Colliery Explosions and Chemical Plant

THERE has recently been an unfortunate series of explosions in coal mines to add to the trials of the men who work in them. The report recently issued (Command 287) on the explosion over two years ago at Blaenhirwaun colliery, Carmarthenshire, reveals some circumstances which might occur in chemical factories. An explosion of firedamp occurred due to an unexpected emission from a "blower" in the roof. This immediately raised into the explosive range the methane content of the air current passing. After careful consideration of the possible sources of ignition the Divisional Inspector of Mines decided that the atmosphere was ignited by sparks produced by friction between the trailing edges of the fan blades and pieces of stone projected into the outlet ducting thus fouling the path of the blades. Flame instantly spread throughout the inflammable atmosphere and reached the highly explosive accumulation at the top corner of the face. At the Safety in Mines Research Establishment it was found impracticable to carry out frictional sparking tests with the fan itself, but experiments were carried out in which discs of an alloy similar to that used for the fan blades were made to rotate under very light pressure in contact with pieces of stone obtained from the supply gate rippings. These experiments proved that at rubbing speeds less than those which would occur in the normal running of the fan, sparks were produced which readily ignited a methane-air mixture. This suggests that in any case where there is the remotest possibility of hard solids being carried in an inflammable gas stream through fan blades, extra precautions are necessary to ensure that the solid is completely separated.

Performance of Finned Tubes

USEFUL comparative data on the heat transfer characteristics of nine finned tubes have been obtained in an open-circuit atmospheric wind tunnel. Types of tube tested included two with different arrangements of circular studs, two with different arrangements of elliptic studs, two with annular fins, two with spirally-wound fins and a plain tube with two longitudinal fins. Results were compared against those obtained with a plain tube. The method can be used to provide design data by transposing experimentally derived figures obtained on this air rig into data for pressurised, high-temperature, carbon dioxide—the conditions in the nuclear-powered steam-raising unit. Using the Nusselt equation the heat transfer from a tube in carbon dioxide, whose properties are denoted by a dash ('), is represented by:—

$$Nu' = \alpha . Re'^{a} . Pr'^{b}$$

Thus, correlating the equations for identical tubes at the same Reynolds number in air and carbon dioxide:

$$h' = h\,(k_f'/k_f)\,(Pr'/Pr)^{b}$$

For this value of h' and this particular fin there is a unique value of the weighted fin-efficiency ϕ' and therefore of the conductance $h'\phi'$ in carbon dioxide. Apparatus and results are described by A. Lymer in *Nuclear Engineering*, 1957, **2**, No. 21, 504. The final assessment of performance of a finned tube is, of course, the effect the particular tube has on the design of the complete steam-raising unit both in capital and running costs. The most significant single factor becomes not so much H, the heat transferred per hour, per foot of tube per °F temperature difference, but the cost per foot divided by H, i.e. the tube cost per B.t.u. transferred per hour per °F.

Pioneers Needed in High-Pressure Reaction Research

THERE is a current scientific version of the traditional advice to pioneers—"Go west young man." The new theme is to go into research on high pressure reactions and it was strongly recommended by Professor O. M. Newitt at a joint meeting of S.C.I. and R.I.C. London Sections. Three *régimes* of high pressure were distinguished by the speaker. Up to about 4,000 atmospheres it is possible to work on a large scale and these can be called industrial pressures. On a small scale, up to about 200,000 atmospheres can now be achieved and this range of pressures form a second *régime* usable in research laboratories. Now a new field is opening up using shock wave techniques in which pressures up to a million atmospheres can be attained. The distinguishing feature of high pressure work is the high probability of collisions between more than two molecules. This usually alters the course of reactions which at lower pressures tend to be more dependent on chain reactions resulting from collisions of pairs of molecules. However, at the highest order of pressure there are theoretical grounds for believing that profound changes occur in matter and that all matter behaves like an electron gas.

Cold Storage for Numbers

IT was not exactly a sting that characterised the tail of the Conference on Low Temperature Gas Separation.* Yet there was some astringency in the concluding remark of Dr. K. Mendlessohn, that more funds should be allotted to the design of computers using low temperatures. For here were the users and designers of the cold-producing plants and they were finding computers valuable for their designs. But the firms using these results could themselves contribute to the improvement of computers, said Dr. Mendlessohn, before formally closing the Conference. Later in private conversation he explained that the use of super-conducting materials could result in a machine the size of an average office being reduced to that of a suitcase. A "popular science" account of super-conductivity has just been given by B. T. Matthias in the *Scientific American*, 1957, November, p. 92. Starting from fairly well known facts—for example, that the electrical resistance of mercury disappears entirely at 4.2°K—Dr. Matthias has put forward some generalisations drawn from his own work. The only substances which can become super-conducting are elements or compounds with an average of between 2 and 8 valency electrons per atom. Within this range those with an odd number of valency electrons per atom become super-conducting at the highest temperatures above absolute zero.

In addition, he continues, the most favourable crystal structure for super-conductivity is one called the beta-tungsten structure—a cubic arrangement of 8 atoms which makes the crystal bulky with considerable space between some of the atoms. These super-conductors are very suitable for computer memory devices. But the same property of being able to handle extremely tiny currents without any loss of their energy also makes super-conductors usable for a

wide range of other sensitive electrical measuring instruments and switches.

* Organised by the Low Temperature Group of the Physical Society and the Institution of Chemical Engineers.

Canadian Refinery Market

AMONG the high executives who composed the largest trade mission ever to visit Great Britain—the Canadian Mission which recently explored the possibility of increasing Canadian purchases in Britain—were a number representing oil and chemical interests. In the opinion of Mr. Trevor Moore, Vice-President of Imperial Oil Ltd., Toronto, one of the members, the recent report of the Council of British Manufacturers of Petroleum Equipment (see *British Chemical Engineering*, 1957, 9, 469) was the "complete guide" for those wishing to sell more of that kind of equipment to Canada. The British team, he said during his visit, had seen the right people and had asked the right questions—"What are your standards?" "What are your designs?" "How soon do you want delivery?" Mr. Gordon Churchill, Minister of Trade and Commerce, leader of the Canadian Mission, pointed out, at a meeting in London, that the members' main purpose was to implement a proposal made last summer by the Canadian Prime Minister, Mr. John Diefenbacker, that some Canadian purchases from the United States might be diverted to the United Kingdom. The switch in purchases of at least 15% aimed at, Mr. Churchill suggested, would not seriously inconvenience Canada's trading partner the United States. The Minister emphasised, as the Petroleum Plant Mission themselves pointed out, the need for offering to potential Canadian customers rapid delivery and quick servicing—requirements which could be met increasingly easily with the help of improving trans-Atlantic telephone services and air-transport facilities.

Progress in Glass Technology

THE first of a new series of general meetings to be organised by the Society of Glass Technology, in Sheffield recently, was a notable success. Lasting over three days so that several papers on related subjects could be read successively, it not merely attracted a large attendance, as had been expected, but it introduced firmly the use of radioisotope-tracer techniques for studying glass flow in furnaces. Moreover, it received an exhaustive critical assessment of the uses and limitations of instrumentation in glass manufacture—from Dr. G. R. Mattocks, British Glass Industry Research Association—which should for long remain a guide. As glass making is still largely an empirical process carried out in furnaces similar in design to those of a century ago, the availability of new techniques for studying and improving it will be very welcome so long as they show substantial advantages over established methods. In, for example, following the passage of sand through the whole glass-making process from washing and grading to glass melting, isotopic methods alone provide the necessary tools, and Mr. R. F. Barker, of Pilkingtons, in a report on a preliminary investigation, showed how this work could be tackled. He had used sand labelled with Ba 140 and La 140. In a separate investigation on the flow of glass in furnaces that he reported, he employed tantalum as a non-radioactive tracer and, subsequently, detected the amounts of the tracer occurring in the finished product by irradiating samples of glass in a high flux of neutrons and measuring the activity induced in the tantalum. Mr. B. E. Moody, United Glass Bottles, described his preliminary examination of a similar problem, using radioactive phosphorus. The Society plans to hold a general meeting lasting over two or three days, twice yearly.

University Architecture

£12 MILLION'S worth of university building is taking place annually in Great Britain and it is essential that it shall be of the right kind—for example, appropriate to its setting both on the site and in society. In addition, it must help to foster the sense of community vital to university life. With the aim of showing some of the better examples of academic building, an exhibition of new university architecture throughout the world has been prepared by a committee under the patronage of H.R.H. The Duke of Edinburgh and with the help of the Arts Council. After an initial showing at Senate House, London University, it has started a tour of other universities, commencing with Oxford, Cambridge and Birmingham. Compactness, which the committee claim is the key to the making of a community, can be obtained, as the exhibits show, in various ways—in a park landscape at Aarhus, in a city in Mexico, in small towns as at Durham, Cambridge and St. Andrews, and in large towns such as Oxford and Harvard. The committee's "ideal" layout, essentially designed for pedestrians with space for a garden landscape, is approached in the master plan for Leicester where, as is shown in the exhibition, the science buildings are to be disposed on a pedestrian acropolis. The change during the past century in universities' attitudes to both architecture and science may be well exemplified in the juxtaposed illustrations of the first science building, 1858, at Oxford—a replica of the Abbot's Kitchen, Glastonbury, which housed the chemistry laboratory so that ". . . . all the noxious operations are removed from the principal pile," and a picture of the equivalent building to be completed, round the corner in 1958, in simple dignified and generous style.

Bowden's Day

FOR Dr. B. V. Bowden, Principal of the Manchester College of Science and Technology, Friday, November 22nd, 1957, will always be a day of special significance. On that day, he had an unforgettable tribute paid to his years of service to the College by H.R.H. The Duke of Edinburgh, who, at the official opening ceremony of the new College extension, declared: "This is Bowden's day. No other man has done so much for his College and to bring this extension into being." The extension, first mooted in 1908, is but the first part of a further development scheme of some 20 acres. The new accommodation comprises some 220 well-lit lecture rooms, laboratories and staff rooms, as well as a large assembly hall capable of seating 600. Heavy laboratory machinery is, in the main, concentrated in the basement rooms (the basement area covers some 2½ acres) and a sub-basement houses the heavy metallurgical laboratory. The extension has added 300,000 sq. ft. floor area to the 200,000 in the old building and an estimate of the final cost of the new extension is some £1,207,000, plus about £5,000 for equipment and furnishings. Local industry has played its part by providing many items of equipment and other pieces of equipment on favourable terms. Thus they have emphasised their continued interest and confidence in the College. New equipment designed to bring the laboratory up to date and comparable to the best in any country has already been largely installed. With the opening of this new extension, Manchester's own College of Science and Technology is well on the way to becoming one of the foremost in the world.

Chemical Engineering in a University

IN his inaugural lecture at Imperial College before a distinguished company, Professor P. V. Danckwerts surveyed the scope of modern chemical engineering and drew attention

to trends in its development. Chemical engineering he pointed out, cannot be practised purely in a University. Like other technologies and applied sciences it must serve industry without losing its independence. It differs from training in the arts—for example in English literature—since it is "training a man for a profession instead of training him to live on his wits." Chemical engineering comprises science, experience and judgment. Of these only the first can be taught at a university. Chemical engineers may be engaged in research, design or operation. For the last category it may be true, as some industrialists say, that personal qualities are more important than technical knowledge. But this kind of balance will not permit advances in technique to be made. For technical progress a grounding in physical chemistry and classical physics is essential with the necessary mathematics. In this context physical chemistry means particularly chemical thermodynamics and kinetics. The new Professor of Chemical Engineering Science also had a shrewd tilt at some research programmes. Not all research is carried out on useful topics, particularly in the pure sciences. Some research is work which in the words of Lucky Jim, "sheds a pseudo light on non-problems" and we should avoid such lines of work. The science of chemical engineering should bring order into places where all has been obscure. It is essentially a matter of intellectual organisation of the material. From this it follows that the most practical job of the chemical engineer is "the optimisation of the flow sheet."

What Birmingham Does To-day

A NOTABLE contribution to the planned increase in University accommodation is being made by Birmingham where the development plans have three inter-related objects. The first is to increase student numbers, particularly in the Faculty of Science. At present they have 3,700 full-time students. In 1966 the number should have risen to 5,000. Of the present students about 1,800 students are registered in the Faculty of Science, which includes mathematical and physical sciences, the biological sciences and the engineering sciences. There is no separate Faculty of Technology. It is likely that by 1965 there will be something like 2,600 or 2,700 students in the Faculty of Science. Secondly, it is hoped that all the Faculties will be brought together on a single site by 1960. Finally, the authorities intend to effect a substantial increase in the amount of resident accommodation at present available. This session about 75% of the students will be living away from home. The Registrar, Mr. Templeman, informs us that present plans for new teaching buildings at Edgbaston involve the expenditure of about £3,000,000. A substantial part of this will be devoted to additional buildings for the various departments of the Faculty of Science. This is over and above money already spent for this purpose in the last ten years. Since 1950 entirely new and thoroughly equipped buildings have been provided for the departments of mechanical engineering, electrical engineering and chemical engineering. Substantial additions have been made to the laboratories of the department of chemistry and a further large chemistry building is about to be started. A new building for the department of physics is half completed and the departments of pure mathematics and mathematical physics will be housed in a block, the construction of which will soon begin.

Dip. Tech.

EIGHTEEN months ago Dip. Tech. was born. Today there are 965 students studying for it in 11 colleges following 37 courses. In June, 1958, one of these colleges—the Birmingham College of Technology—will conduct the first finals examination. This is part of a big expansion programme intended to increase the annual output of technologists from 5,000 to 9,000 a year in addition to a smaller number coming from the universities. In a statement accompanying the first report of the National Council of Technological Awards, Lord Hives said that 50 courses had been approved out of 104 submitted. These figures showed he thought that they had insisted on high standards but that these high standards were also realistic. His aim was to convince school teachers that courses in technical colleges are appropriate for their best boys and girls and that the Diploma in Technology will be a higher mark of distinction. The Dip. Tech. students will be the honours students of technology. Lord Hives also pressed industries which had not yet made up their minds about the importance of training technologists to examine their future developments in terms of new processes and new materials and to make a contribution in support of these courses. In reply to questions about the supply of candidates for these courses Sir Harold Roxbee Cox, Vice-Chairman of the Council, was more than reassuring. First there was the bulge which was now passing through the schools; in addition more school children were going into the Science Sixth and a larger proportion were staying at school over the age of 15. For all these reasons Sir Harold was confident that by the middle of 1960 there would be many more candidates than places. A healthy development is the Council's insistence that all courses cover liberal studies and informal activities. For the moment they have been satisfied to accept a statement of the intention of the college to develop a liberal approach in the curriculum rather than insisting on submission of detailed syllabuses. We must also hope that arts students will be given a reciprocal opportunity to understand something of scientific and technological developments.

Educational Expansion in Perspective

THIS month in this column we report several examples of higher educational expansion. But is it quick enough or large enough? More fundamentally—is it soundly underpinned by improvements in the schools? Here is a comment from *The Schoolmaster* on the schools programme: "The blunt fact is that block grants mean less money for education not more and the Government knows it. But unless more money is found and more capital investment permitted for education even the present pace of development is imperilled and all talk of catching up with the Russians is like trying to build an earth satellite with an engine consisting of a piece of elastic and a bent pin." They go on that it is "time the Government stopped boasting about educational expansion while at the same time sponsoring changes which have precisely the opposite effect"; the authorities should "make into reality high flown talk about investing heavily in the education of the nation's children."

Link this with some facts quoted in a fascinating, informative account entitled "Education in the Soviet Union."* Despite years of scarcity and austerity since the 1917 revolution, the educational system has received extremely favourable treatment. The estimated expenditure per head of the population in 1953 was $91 for the U.S.S.R. and $24 for the United Kingdom. The authors comment that current housing and living conditions in the Soviet Union lag behind the West. But there has been such remarkable progress in education that it is now possible to compare Soviet and British education on something like equal terms, not always to the advantage of the latter. This presents a challenge that those responsible for education in Western democracies should be prepared to meet.

* Joint Report of a Study Tour, Autumn, 1956. Published by the Educational Interchange Council, London, S.W.1

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A HEYWOOD PUBLICATION
British Chemical Engineering

Science as a Liberal Study

ONE of the questions Dr. Linstead dwelt upon in his recent Ninth Hinchley Memorial Lecture, "An Education for our Times?", was, in his own words, "Should scientists and engineers be taught non-scientific subjects at the university?" In answering this controversial and unresolved question, Dr. Linstead revealed himself to be firmly opposed to the introduction of compulsory and examinable non-scientific subjects into existing courses, but with two qualifications. First, the university or college should make a continuous and organised effort to provide facilities whereby a student can broaden his outlook, interests and experiences; and, second, certain allied subjects, such as languages and the history of science, should to some extent be studied in an organised way. This, in a sense, is merely re-phrasing the question, for it is largely in drawing the line of demarcation between these two qualifications, and in deciding how to put the proposals into effect, that dispute arises.

In summarising the discussion, Sir Hugh Beaver took up this point and queried whether science could not be taught as a humanity. This suggestion conflicts with tradition which looks upon the sciences and the humanities as irreconcilable, and if the division is weaker than of yore the recent words of Professor Hugh Trevor-Roper testify to its continuance, for in his inaugural lecture as Regius Professor of Modern History at Oxford he declared that the methods of studying the humanities and the sciences must differ radically.

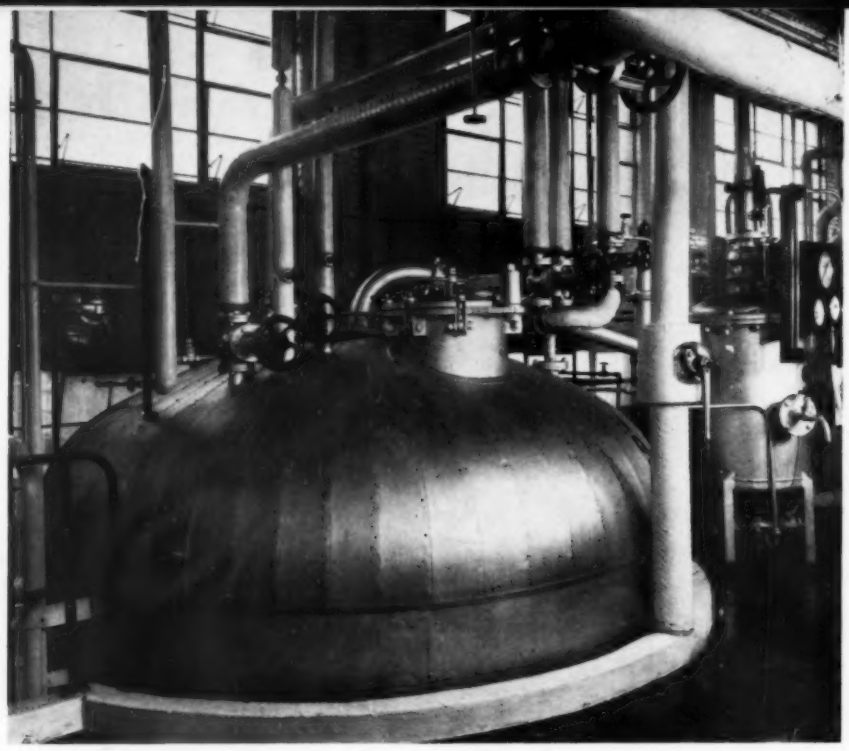
The difference must surely lie in degree rather than in kind. What is there about the study of the humanities which should be so distinctive? It is not absence of a formal discipline, for languages have their grammar and syntax, history its dates and facts and even laws. It is not a monopoly of imagination and personal interpretation, for these are the life-blood of advancing science.

In fact, the humanities are usually so called because they claim to have a humanising effect upon those who study them—or, according to Arnold's definition that "civilisation is the humanisation of man in society", they make a man more civilised. Must it be concluded that, without a study of the humanities, a person cannot become civilised in the sense in which the term is used here? Or that science and its related subjects exert an opposite effect? Whilst this proposition might gladden the hearts of the protagonists of that eminent and highly civilised classical scholar, the late Dr. Gilbert Murray, we do not believe it will commend itself to many of our readers.

Perhaps this paradox may be resolved by examining more closely what is entailed in the study of the humanities. The classic examples are Greek and Latin. Yet the study of Greek or Latin does not only mean learning the language, but also a detailed study of Greek and Latin literature, not just as words locked within a book, but in relation to the people who lived and died when the literature was written. Effort is made to understand the people, not just to learn the words they spoke, but why one word was used instead of another, what they thought and believed, how their society was organised, how these things influenced or were influenced by their language. Surely, what is humanising about the study of Latin or Greek is not the language, but its close connection with people? The study of the manipulation of words can be no more humanising and no less than the study of the manipulation of numbers or algebraic symbols. May not, then, the study of any subject be humanising, provided it is closely connected with man's everyday life?

In this case it is difficult to escape the conclusion that the study of science and engineering can be humanising, for there must indeed be few aspects of modern life which are not in some way connected with these related subjects. This is not to say that their study is in itself humanising, but only that the potential exists; and if the task of realising this potential is that of the teachers and lecturers, the responsibility for attaining it must rest with the educational system and its apparatus which still allow science and technology to be taught as subjects isolated from the main stream of life. There is no doubt that many colleges were influenced in their development by short-term utilitarian aims which tended to obscure broadness of outlook. What is wanted is a sense of the place of these subjects in life, an understanding that along with the so-called humanities they are an essential part of culture. The followers of Professor Trevor-Roper should be reminded that the methodology of science is itself a powerfully humanising factor, which it seems they prefer to ignore.

If the teaching of science and technology in the matter of perspective leaves much to be desired, then properly organised encouragement and guidance of teachers would go a great deal of the way to remedying the situation. At least this would be a step as effective as imposing further fields of study upon the student, and the outcome would be better scientists and engineers more conscious of their role in the affairs of man.



Small unagitated fermenter vessel seen from main operating floor.

THE PRODUCTION OF ANTIBIOTICS

Methods of manufacturing antibiotics are reviewed and design features of plants employed for this purpose are outlined

by G. ROSS, B.Sc., A.M.I.Chem.E.

THE term antibiotics is applied to those chemical substances produced by micro-organisms which can inhibit the growth of, or kill, bacteria or higher fungi. Most of these substances are also relatively toxic to higher forms of life, but a few are useful in combating diseases in animals and man.

The first evidence of the existence of such substances was observed in 1907. Penicillin, produced by the mould *Penicillium notatum*, was the first material found to be safe for the treatment of diseases in man. It was discovered by Sir Alexander Fleming in 1928, and had its first clinical trials in 1941. It was first produced by the surface culture method, but in 1944 the submerged culture process, which is now generally used for the production of all antibiotics, was adopted. The two principal types of antibiotic are the penicillins and streptomycins, produced by strains of moulds and actinomyces respectively.

Culture Methods

Surface Culture: This was the method originally employed to produce antibiotics, and is an extension of the usual laboratory technique for the growing of micro-organisms.

Mr. Ross *graduated with Honours in Chemical Engineering at Birmingham University in* 1952. *He was employed in the Development Department of the Distillers Co. (Biochemicals) Ltd. before taking up his present position in the Acid Division of Simon Carves Chemical Plant Department.*

In the case of penicillin, the mould was grown on the surface of a shallow layer of nutrient broth, about 1.5 to 2 cm. thick, contained in a suitable vessel. Winchester quart bottles, milk bottles and flasks specially designed for stacking were all used commercially. The broth was inoculated with a culture of *Penicillium notatum*, and then maintained at about 80°F for seven days. A mat of vegetation was thus produced on the surface of the broth by the growing mould, the penicillin being harvested by withdrawing the medium from under this mat. Eventually, methods were developed for continuous or semi-continuous operation, but even so it was a very difficult and costly process to operate, requiring specialised techniques on the part of the operators. Yields of penicillin in the region of 30 to 60 International Units per ml were obtained.

Submerged Culture: Strains of mould were ultimately produced which would grow within the body of the nutrient liquid. This obviously reduced the area of plant floor space required for a given production and also rendered the process more amenable to operation by normal chemical process techniques. The advantages of the submerged culture method may be summarised as follows: (1) economy of labour and space; (2) better control of the process variables; (3) higher productivity; and (4) simplification of purification techniques.

The batch process, described in detail later, is generally used, but continuous processes also have been developed. Yields of penicillin in the region of 5000 International

Units per ml have been achieved using the submerged culture method with the most recently developed strains.

Suitable Strains of Organisms

Strains have been developed which give higher yields of antibiotic on an industrial scale, and which do not produce by-products that interfere with the recovery processes. Strain selection has been assisted by the use of physical agents to cause mutations, for example, ultraviolet light, X-rays, neutron bombardment or heat; and also chemical agents such as nitrogen mustards or colchicine.

Maintenance and Propagation

Stock cultures may be maintained in the laboratory by, for example, the inoculation of sterile sand with mould spores, or by the freeze drying of spores in milk or agar. The propagation of the culture up to the final plant fermentation is accomplished in a series of steps. Thus a solid medium such as an agar slant may be inoculated with a little of the stock culture, and incubated until sporulation occurs. The spores thus obtained are suspended in sterile water and inoculated into about 300 ml of nutrient solution. This stage would be carried out in the laboratory, in a flask maintained at the correct temperature for optimum growth. Aeration is achieved by agitating the flasks in a shaking machine. The culture obtained is then available for inoculation into the seed fermenter vessel.

Submerged Fermentation Process

In outline, the plant-scale fermentation process consists in inoculating the laboratory culture of the growing organism into a broth or mash of nutrient materials, contained in a fermenter vessel. The usual antibiotic producers require air, and this is admitted to the broth through a sparge pipe. Cooling coils remove the heat produced during fermentation. After fermentation, the broth is filtered, and the penicillin or other antibiotic contained in the solution is recovered, by solvent extraction for example (see Fig. 1).

The laboratory culture, produced generally as described above, is inoculated into the seed fermenter vessel which represents the first stage of plant fermentation. This vessel may contain about 350 gal. of sterile nutrient broth previously prepared in a cooker, and transferred to the seed fermenter by compressed air. The broth is continuously agitated during fermentation, air being also continuously admitted, to provide the oxygen required for the process and to assist with the agitation. The vessel is maintained with a slight positive pressure inside to prevent the ingress of micro-organisms from the atmosphere.

Heat is produced during the fermentation by the reactions taking place, which include the oxidation to CO_2 of carbohydrates in the broth. In addition, there is a further heat input equivalent to the mechanical energy of agitation. This heat gain is balanced by heat losses from the vessel due to radiation and convection, and to the latent heat of evaporation of the water vapour which saturates the air leaving the vessel. In addition, however, in order to maintain the temperature of the medium at its optimum value, it may be necessary to remove heat by passing cooling water through a jacket or internal coil associated with the vessel.

In streptomycin production, the optimum growth of the micro-organism will be reached in the seed vessel after fermentation for a period of about 40 hours. Fermentation for longer than the optimum period will allow sufficient depletion of the nutrients in the broth to restrict the further growth of the organism, leading to spore formation. During the final hours of this fermentation, an empty fermenter vessel is prepared by washing down and sterilising, and is then charged with sterile nutrient broth, amounting to up to 8000, or 16,000 gal., according to the size of the vessel. The culture in the seed vessel is next transferred by means of compressed air to the fermenter, through a previously sterilised line.

The fermentation in the fermenter proceeds along similar lines to that in the seed vessel, but continues for 80 or 90 hours. In the case of a fermenting broth of, say, 16,000 gal. a culture from a second seed vessel may be added a few hours after the first. It is important to ensure that sterilised lines and broth in the fermenter vessel are at the correct temperature to receive the seed, which is very temperature-sensitive. High temperature will kill all or part of the growing organisms, and temperature in the fermenter much below the optimum will so retard the rate of growth that the heat generated by the reaction may be insufficient to raise the temperature of the broth to the correct value, due to the heat losses mentioned above.

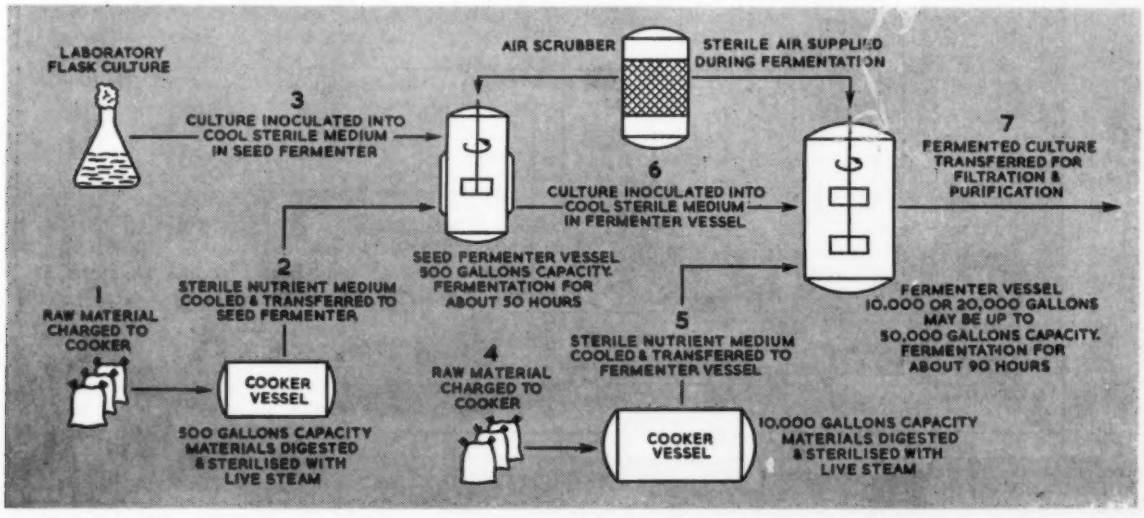

LABORATORY FLASK CULTURE
3
CULTURE INOCULATED INTO COOL STERILE MEDIUM IN SEED FERMENTER
AIR SCRUBBER
STERILE AIR SUPPLIED DURING FERMENTATION
7
FERMENTED CULTURE TRANSFERRED FOR FILTRATION & PURIFICATION
6
CULTURE INOCULATED INTO COOL STERILE MEDIUM IN FERMENTER VESSEL
SEED FERMENTER VESSEL 500 GALLONS CAPACITY. FERMENTATION FOR ABOUT 50 HOURS
2
STERILE NUTRIENT MEDIUM COOLED & TRANSFERRED TO SEED FERMENTER
1
RAW MATERIAL CHARGED TO COOKER
FERMENTER VESSEL 10,000 OR 20,000 GALLONS MAY BE UP TO 50,000 GALLONS CAPACITY. FERMENTATION FOR ABOUT 90 HOURS
5
STERILE NUTRIENT MEDIUM COOLED & TRANSFERRED TO FERMENTER VESSEL
4
RAW MATERIAL CHARGED TO COOKER
COOKER VESSEL
500 GALLONS CAPACITY MATERIALS DIGESTED & STERILISED WITH LIVE STEAM
COOKER VESSEL
10,000 GALLONS CAPACITY MATERIALS DIGESTED & STERILISED WITH LIVE STEAM

Fig. 1. Simplified flowsheet showing sequence of operations in the production of antibiotics from the raw material stage to fermented culture stage prior to transference to filtration and purification.

As fermentation proceeds, foaming is liable to occur due to the viscous, rather slimy nature of the broth and to the high aeration rate employed. This foam may occupy several feet above the surface of the broth, and if unchecked can lead to serious loss of material by entrainment in the air leaving the vessel. Peanut oil is used to break this foam, and is added continuously to the vessel throughout the fermentation. The oil can, however, cause trouble during filtration if it has not been metabolised by the broth, and so additions must be restricted during the later stages of fermentation. A plunger-type metering pump is therefore employed to supply the oil. The stroke of this pump is generally under control by the plant operator, although systems have been proposed to automatically control the rate of the pump according to the level of foam in the fermenter. This may be done, for example, by the use of probes inserted in the vessel; increase in the foam level completing an electrical circuit through the probe. Where foaming has been allowed to get seriously out of hand it may be necessary to stop agitation of the broth, and possibly reduce the aeration rate to the vessel. Normally, however, agitation is continuously employed and the aeration rate remains unchanged throughout the fermentation.

Sampling and Testing

The progress of the fermentation is checked by examination and testing of samples of the fermenting broth. These samples are withdrawn from a convenient point on the side of the vessel, the sampling spout being kept sterile with live steam when not in use. The smell and appearance of the sample are good indications of the state of the fermentation. Thus a sour smell, or discoloured appearance, are indications of the presence of contaminating organisms. Similarly, towards the end of a fermentation a thin, watery broth may indicate that growth is not proceeding properly. The broth is also examined under a microscope which provides another check on the healthiness or otherwise of the growth. Occasionally, the presence of contaminants in the broth may actually be seen, but this would indicate exceptionally heavy contamination which would have already been revealed by the other tests.

A little of the broth is also streaked across agar jelly, incubated in a sterile atmosphere, and examined perhaps eight to twelve hours later when the presence of a competing organism on the streak may be seen under a low-power microscope. A sample is taken from each seed vessel or fermenter vessel at least once a shift, but more frequently if any fermentation is in doubt. During the main fermentation, samples will be taken for the measurement of some parameter which gives quantitative evidence of the rate of growth. Thus, in streptomycin production, samples are withdrawn at intervals of eight hours, and later twelve hours, for estimation of the presence of sugars and for comparison with the concentration of this sugar throughout a healthy fermentation. After fermentation, other tests are carried out to determine the assay or concentration of the antibiotic in the broth, etc.

Sterilisation Techniques

The principal difficulty in the operation of this basically-simple process is that of ensuring that the delicate growing organism does not have to compete with other more hardy forms of life. These competitors include the wild yeasts and bacteria which are present in the nutrient materials and water which constitute the broth, in the air which the organism requires for its growth, and on the surfaces of the fermenter, pipe-lines, etc.

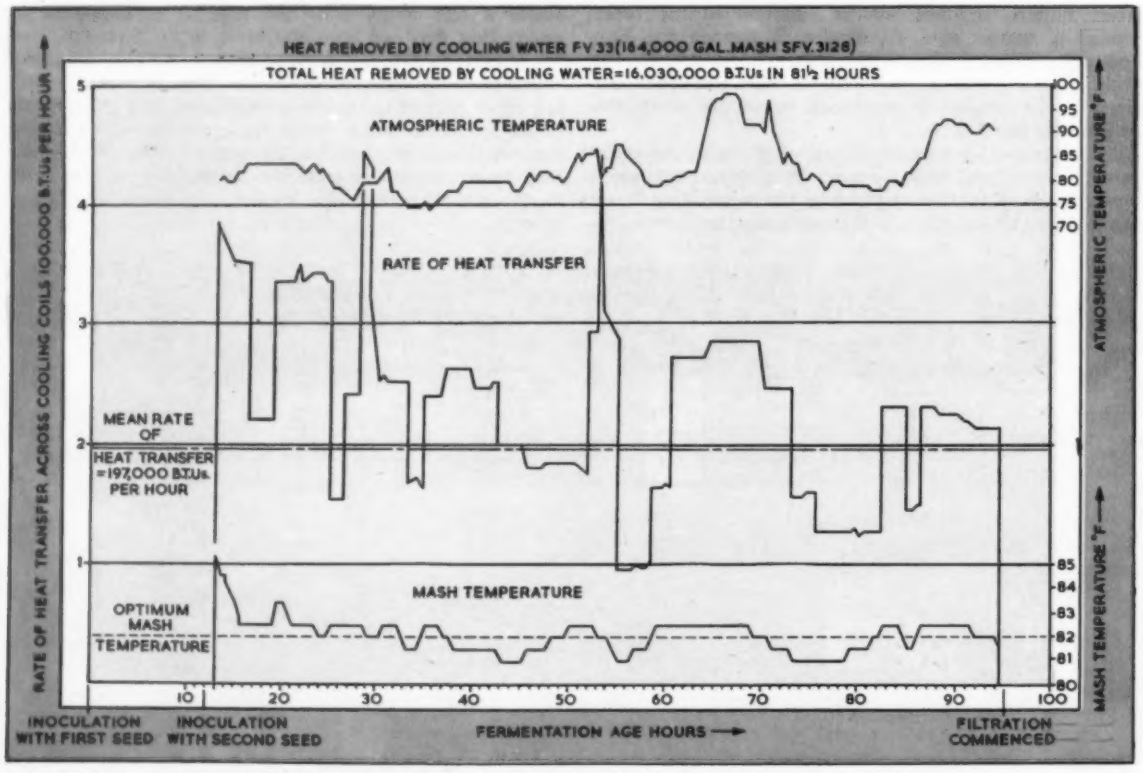

HEAT REMOVED BY COOLING WATER FV 33(164,000 GAL. MASH SFV.3128)
TOTAL HEAT REMOVED BY COOLING WATER=16,030,000 B.T.Us IN 8½ HOURS
ATMOSPHERIC TEMPERATURE
RATE OF HEAT TRANSFER
MEAN RATE OF HEAT TRANSFER =197,000 B.T.Us. PER HOUR
MASH TEMPERATURE
OPTIMUM MASH TEMPERATURE
RATE OF HEAT TRANSFER ACROSS COOLING COILS 100,000 B.T.Us PER HOUR
ATMOSPHERIC TEMPERATURE °F
MASH TEMPERATURE °F
FERMENTATION AGE HOURS
INOCULATION WITH FIRST SEED
INOCULATION WITH SECOND SEED
FILTRATION COMMENCED

Fig. 2. The above figure indicates rates of heat transfer during a streptomycin fermentation using manual control.

These organisms can affect the progress of the fermentation in several ways. Thus in the case of penicillin, it has been observed that many organisms produce *penicillinase*, an enzyme which destroys the penicillin. In addition, all contaminating organisms will retard the desired growth by consuming the nutrients in the broth. Unwanted by-products not actually harmful, but difficult to remove in the final recovery processes, may also be produced.

It is unfortunate that the conditions required for the growth of the antibiotic producer itself are also ideal for the growth of numerous other microscopic forms of life. It is therefore proposed to describe the fermentation process in greater detail by first considering the measures which are taken to prevent contamination.

Sterilisation of the Nutrient Broth: This is carried out in a vessel known as a cooker. In streptomycin production, the nutrient broth used is a mixture of soya meal and glucose in water, some metallic salts also being added. In the case of penicillin production, corn steep liquor, a by-product of the corn starch industry, and at one time a waste material, forms an ideal nutrient broth.

The materials are transferred to the cooker, where they are brought up to the sterilisation temperature of 250°F by the admission of live steam, the vessel being kept under the steam pressure of about 15 psig. The object of this procedure is principally to sterilise the materials, but some digestion is also necessary. The length of the cooking cycle has to be so adjusted as to ensure sterilisation without causing excessive break-down of the materials.

The broth is then pumped to the fermenter vessel; the latter, together with the pump and pipe-line, have been previously sterilised by 15 psig steam for at least one hour. On its way to the fermenter, the broth is passed through a rack-type cooler, in which its temperature is brought from 250°F to a little above the optimum fermentation temperature of about 82°F. After the transfer of a seed culture or of nutrient liquor, the line which has been used for the transfer is washed out with water at 250°F. The sterilising process causes the *p*H of the nutrient liquor to fall. After transfer to the seed fermenter or full-scale fermenter, the liquor is adjusted to approximately neutral *p*H by the admission of soda ash or caustic soda solution.

Sterilisation of the Seed Vessel or Fermenter: This is carried out simply by admitting steam into the top and thus displacing the air in the vessel from the bottom. The vessel is then kept under full steam pressure at a temperature of at least 250°F for at least one hour. It is important to ensure that condensate is not allowed to collect in the bottom of the vessel, as this can permit that part of the vessel under the water to cool down from the sterilisation temperature. After sterilisation, the vessel is cooled by passing sterile air through it, and is then ready to receive the nutrient broth.

Sterilisation of the Air: The simplest and commonest method is to pass the air through a previously sterilised bed of activated carbon in a carbon scrubber. This bed may be up to say 10 ft in diameter by about 6 ft deep, and will consist of carbon particles of about 6 to 30 mesh, supported by a bed of pebbles above a perforated plate. A bed of the size given above would be used to treat about 5000 to 10,0000 Ncfm of air and would have an initial pressure drop of 2 or 3 in. water gauge. The pressure drop across the bed will gradually increase due to dust build-up and to reduction in the size of the carbon particles. After a period of some weeks or months, the pressure drop will have risen to an uneconomic limit and it is then necessary to rescreen or replace the material.

The carbon bed actually removes spores and bacteria from the air by a process of filtration and adsorption. The method is not completely effective, as contamination of fermenting broth does occur, particularly in summer when

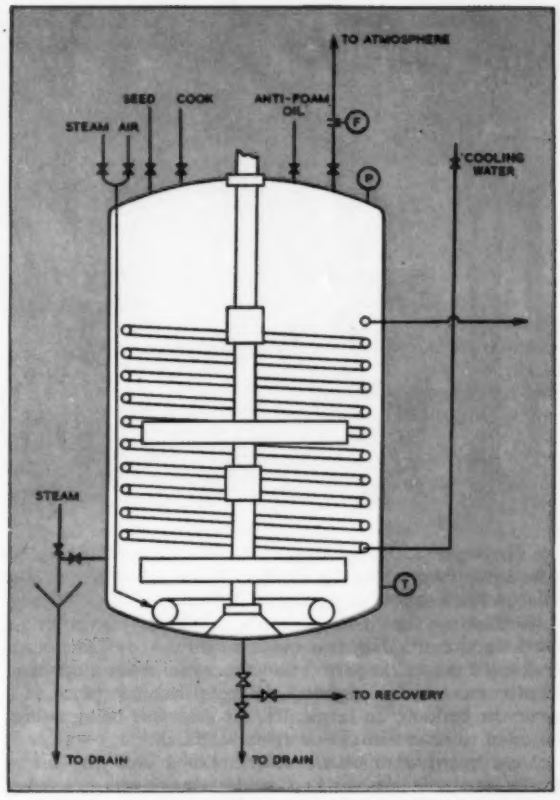


Fig. 3. Diagrammatic arrangement of fermenter vessel: F = Flowmeter; P = Pressure indicator; and T = Thermometer.

the air contains a higher proportion of organisms. The scrubber must itself be sterilised with steam in a manner similar to that employed for the fermenter vessel. This is done once a week. Since a continuous air supply is needed, two scrubbers are required, one working whilst the other is being sterilised. For the same reason, two air mains are required between scrubbers and fermenter vessels. Each air-line is used for 24 hours and then resterilised. Cotton wool or glass wool have also been proposed as alternative filtration media in the scrubber. The other principal methods of air sterilisation which have been proposed include:

(1) Heating the air to the sterilisation temperature. This is obviously an expensive and unwieldy method, since the heat input required would be considerable, and it would have to be removed before the air was admitted to the vessel as the high temperature would kill the growing organism.

(2) Subjecting the air to high-frequency shock waves, such as compressing it in a Roots blower.

(3) The use of electrostatic precipitation to remove the bacteria.

(4) Finely dispersing the air through towers containing some non-volatile antiseptic fluid, such as dilute NaOH. It is necessary, of course, to ensure that carry-over of antiseptic into the fermenter vessel does not occur.

Loss of production due to contamination by air has been estimated as about 5%, for either wet or dry scrubbing. The air pressure provided by the compressors must be sufficient to overcome the pressure drop across the air scrubber and also the static head of about 20 ft of broth in the fermenter. In addition, it is customary to operate

Fig. 4. Fermenter vessels of 10,000 and 20,000 gallons capacity seen from ground-floor level.

the fermenter at 3 or 4 psig, to exclude non-sterile air. To overcome these pressure losses, the air pressure at the inlet to the scrubber is usually of the order of 20 or 30 psig.

Sterilisation of Anti-foam Oil: During fermentation, frothing and foaming can occur as previously mentioned, and anti-foam oil is passed into the vessel from a positive-displacement metering pump. Non-sterile oil is piped to a reservoir beside each fermenter, the reservoir being steam-jacketed to maintain the contents at 250°F.

Sterilisation of Transfer Lines: Lines used to convey broth or sterile air are kept under steam pressure when not in use. All lines are sectionalised and provided with valves at the end of each section, so that those sections not in use can be kept under steam pressure. Branch lines to and from a fermenter vessel are also kept under steam when not in use. Valves are placed as closely as possible to branches or tees to keep to a minimum the length of stagnant sections of line. Thus broth is admitted to a fermenter from a header, by way of a branch line, which would be provided with a valve at each end and which would be kept under steam pressure throughout the fermentation, the header meanwhile being available for broth transfers to other vessels. It is important that there is a steady and regular fall along all lines to ensure drainage of condensate. A sagging line will accumulate broth and cold condensate and will ultimately become a source of contamination.

Valves: When gate or globe valves are used, it is important to ensure that they are well sterilised, as the valve spindle can be a source of contamination, particularly when rising spindle valves are employed. For this reason steam may be admitted and condensate removed by way of the valves. Gate valves with bronze gates and cast-iron bodies are preferred, the latter being provided with several cast-iron bosses on either side of the gate. When a steam inlet or drain connection is required a hole is easily drilled and tapped through this boss. The valve packing and lubricant employed must be capable of withstanding the sterilisation temperature of 250°F.

Saunders-type diaphragm valves, which have also been used, have the great advantage that they eliminate contamination by way of the valve stem. They have the disadvantage, however, that the diaphragm is liable to have a short life due to the cycle of intermittent heating and cooling to which it is subjected.

Steam Traps: There is a considerable consumption of steam in the sterilisation of lines and vessels, but this consumption can be reduced by the use of steam traps. Steam trapping is, however, a difficult business, as the condensate will wash out broth left in lines and vessels. This will quickly cause blockage of the trap as well as rendering the condensate unfit for re-use.

Strainers fitted before the traps also quickly become blocked. Hence if an attempt is made to reduce wastage by the use of steam traps, it is necessary to make frequent inspection to see that these are operating satisfactorily. A blocked steam trap will allow condensate to accumulate, and thus prevent complete sterilisation of the vessel. Some improvement may be effected by making the strainers easily removable, so that they can be cleaned out by the plant operator each time a vessel is sterilised.

Since purging of air is a preliminary to the sterilisation of a fermenter, steam traps of the thermostatic type, which will pass air when cold, are very useful.

Design of Fermentation Vessels

A height to diameter ratio of 2 or 3 : 1 is generally employed, though this ratio may be greater in the case of seed vessels to obtain a longer contact time with the air. The operating volume is generally about three-quarters of the total volume available, to allow for foaming. It is necessary to ensure that there are no ledges or pockets inside the vessel which could allow liquid to collect or remain during sterilisation. Such pockets could prevent full sterilisation of these points from being obtained. They will also permit the accumulation of deposits during successive fermentations, by the collection of broth, evaporation of water during sterilisation, collection of broth during the next fermentation and so on. Where a pocket is unavoidable, it must be provided with a drain hole.

Aeration: Most fermentation processes for the production of antibiotics require a considerable quantity of air. For example, for streptomycin production about 6 Ncfm of air per 100 gal. of broth will be required. This figure corresponds to a superficial velocity of the order of 2 to 6 fpm for fermenter vessels, the superficial velocity for seed vessels being somewhat lower and about 1 to 4 fpm.

The device generally used for the admission of this air is a simple circular sparge pipe located at the bottom of the vessel and drilled with a suitable number of holes. Other devices have been tried, including porous ceramics and perforated metal discs giving very small air bubbles. These are rather liable to blockage with broth however. In smaller vessels high-velocity nozzles have also been used with considerable success.

Agitation: Due to the heavy growth of the organism which is obtained in these vessels, the broth becomes ultimately of very high viscosity, and, in addition to the agitation provided by aeration, mechanical agitation is also required.

It is now known that the early wartime fermenters were underpowered, and were designed to operate with an input of from 0.2 to 0.3 hp for 100 gal. of aerated broth. Newer vessels, such as those previously quoted, are designed to operate at inputs of from 0.8 to 1.0 hp a 100 gal. Older units have now mostly been repowered. The result of underpowering is, of course, that the rate of growth obtainable is much reduced.

The agitators employed are of the slow-speed paddle type, revolving at from 100 to 300 rpm. The design of the agitator shaft and bearings must take account of the fact that the vessel will be at a temperature of 250°F for a short period every few days, although the agitator would, of course, not run at these times. Because of the problems of leakage and contamination, the bottom bearing is internal and unlubricated, except for the lubrication provided by the broth itself. The gland where the shaft enters the vessel was a frequent source of contamination at one time, but the use of mechanical seals has overcome this trouble.

Cooling: Internal coils are obviously preferable to external jackets from the point of view of heat transfer. However, they must be of all-welded construction, with no flanged joints inside the vessel, since a leak of water into the vessel will certainly cause contamination. With an agitation input to the broth of 0.8 to 1 hp for 100 gal., an overall coefficient of heat transfer of about 100 Btu/hr sq. ft F° may be expected. About 3 sq. ft of coil surface would be provided for each 100 gal. of liquor. Fig. 2 indicates rates of heat transfer during streptomycin fermentation using manual control.

Seed Vessels: These vessels are used for the preparation of the seed or inoculum required for the final fermentation, and usually have a capacity of about 500 gal. They are equipped with a jacket for cooling water, an agitator of about 5 hp, and a sparge pipe provided with connections for the admission of steam or air. A manhole giving access for cleaning and maintenance is also required, as well as lines for air and steam for discharging to the fermenter or to drain and for sampling. There must also be a means for transferring the laboratory flask culture into the vessel. One method employed is to fit the vessel with a valve and branch pipe, the latter being at a few degrees from the vertical and provided with a length of flexible rubber hose on the end. This is kept sterile by the admission of steam when not in use, though sterilisation by chemical methods or flaming may be used.

To transfer the seed, the plant operator will lower the pressure in the vessel to atmospheric, and open the valve below the rubber hose. A second operator would simultaneously remove the cotton-wool plug from the neck of the culture flask and invert the flask into the rubber hose, making an airtight seal round the flask whilst the transfer is taking place. This operation must be carried out quickly to avoid contamination, and requires skill and co-ordination on the part of those performing it.

Another method is to fit the vessel with a rubber diaphragm through which the culture may be injected by means of a coarse hypodermic needle.

Fermenter Vessels: These may be of up to 10,000 or 20,000 gal. capacity, and are provided either with a cooling jacket or with internal cooling coils. They are usually fitted with paddle-type agitators requiring about 160 hp for a 20,000-gal. vessel, the latter being about 15 ft in diameter, the agitator motor and reduction gearing being mounted on the top. A sparger for the admission of steam or air, a manhole and probably a fixed ladder for access to the bottom of the vessel will also be provided as standard.

In addition, the vessel will be equipped with connections for: (1) air and steam supplies to the sparger; (2) broth from cooker and inoculant from seed fermentation vessel; (3) soda-ash liquor or caustic soda for the adjustment of *p*H; (4) anti-foam oil; (5) discharge to drain and to the filtration plant; (6) sampling; and (7) air discharge to atmosphere; for example, to the roof above the vessel.

Extraction and Purification

Filtration is the first step in the recovery of the antibiotic from the fermented broth. In the case of penicillin, the mycellial growth is easily filtered off and is used as a cattle food, penicillin being recovered from the filtrate by means of solvent extraction. The rather greasy growth obtained in the production of streptomycin quickly causes blinding on filter cloths, and the use of filteraid is necessary. The broth is first acidified to *p*H 2 to 4, and is then filtered on a rotary filter on which a precoat of filteraid has previously been built up. Additions of filteraid are also made to the broth before filtration. The filtrate is then neutralised to *p*H 7 to 7.5.

Recovery of streptomycin is carried out by adsorption on charcoal or a cation-exchange resin, and elution with acidified alcohol in the first case or with dilute acid in the second case. The eluate is then further purified by means of chromatography, streptomycin hydrochloride in 80% methanol being passed through alumina or activated carbon.

A few remarks about the role of the chemical engineer are appropriate in conclusion. Fermentation may be considered as a unit process, and a detailed knowledge of the microbiology and chemistry of the process is not required to make it work. The fermenter may be considered as a stirred reactor, the heat of reaction being supplied by the oxidation of the carbohydrates present in the liquor. It will be seen that the elucidation and estimation of the effect of the various factors concerned—namely, rates of agitation, aeration and cooling, shape and size of the fermenter and others, which influence the rate of reaction—are all recognised fields for the chemical engineer. We can expect greater attention to them to yield significant improvements in manufacturing processes.

The author wishes to thank the Distillers Co. (Biochemicals) Ltd. and also the Institution of Chemical Engineers for permission to publish this article, which is based on a paper given to the North-west Branch of the Institution (Students and Graduates' Section).

Manufacture of Polio Vaccine

AT THE NEW £250,000 plant of Burroughs Wellcome & Co., Beckenham, Kent, where the manufacture of poliomyelitis vaccine has just commenced, the maintenance of sterility in the correct places, an essential condition, is helped by a novel design of the three-floor building in which the process takes place. Spacious false storeys, called "voids", have been built beneath and above each floor for containing the numerous service ducts, and service-plant rooms separate from the working laboratories are provided at one end of the building, with the total result that service maintenance can be carried out with minimum disturbance of the working space. Uniquely, the production of the vaccine involves the large-scale growing of a virus by tissue culture. At present the tissue, monkey-kidney cells, is cultured in thin sheets in bottles, in a way reminiscent of the early processes for manufacturing penicillin. It is thought, however, that, after more information has been gathered about the growth processes and requirements of tissue and virus, the whole manufacture of the vaccine may well be placed on a "full chemical engineering basis".

DESIGN OF SIEVE-TYPE DISTILLATION PLATES

The author reviews the various factors affecting the performance of sieve plates and, by means of a worked example, shows how they may be designed

by H. E. EDULJEE, Ph.D., A.M.I.Chem.E.

DISTILLATION is a process involving heat and mass transfer and, ideally, if the effect of plate design on the various transfer coefficients is known, then it should be possible to design a plate with the best transfer characteristics. Unfortunately, this is not at present possible for the following various reasons. (a) The phenomena on a distillation plate is so complicated that it is difficult to isolate the various transfer coefficients and to study the effect of plate design on them. (b) Other considerations, such as hydraulic gradient, entrainment, liquid height in downcomers, etc., are as important as transfer coefficients. (c) A detailed study of the fundamentals of distillation plate behaviour and performance has not been made till recently and such data as have been published allow little more than inadequate correlation of some of the factors affecting distillation plates.

During the last few years the American Institute of Chemical Engineers has encouraged a considerable programme of industrially-sponsored work on the study of bubble-cap plates and adequate data for this type of plate will shortly become available. In the absence of such fundamental data, the practice has hitherto been to correlate the performance of existing columns with the dimensions of various parts of the plate and so evolve a "rule of good practice" as an aid to design. The bubble-cap tray has been fairly well studied[1,2,3] and such trays can now be designed with a fair degree of confidence. Sieve-type or "perforated" plates have been less fortunate; although they are the simplest type of distillation plates and have been known for nearly a hundred years, certain misconceptions regarding their stability and range of operations drove them out of fashion.

Size and Number of Holes

Perforated plates so far studied have had holes ranging from 0.025 in. to 0.375 in. in diameter. Mayfield *et al.*[4] have suggested $\frac{3}{16}$ in. (0.1875 in.) diameter as an optimum compromise between efficiency and cost. Jones and Pyle[5] recommend hole sizes between 0.1 in. and 0.25 in. diameter, and the total hole area should be between 5 to 15% of the column cross-sectional area. The holes are normally arranged at the apices of equilateral triangles and the pitch of the hole centres is about three times the hole diameter. For industrial towers, hole diameters of $\frac{1}{8}$ in., $\frac{3}{16}$ in. and $\frac{1}{4}$ in. pitched at $\frac{1}{2}$ in., $\frac{3}{8}$ in. and $\frac{3}{4}$ in. spacings respectively are of greatest interest.

If the conditions of liquid flow permit it, distillation plates should be provided with chord weirs rather than making the tops of circular downcomers act as weirs, and there should be an inlet as well as an outlet weir. The length of chord weir is usually 0.75 times the tower diameter. Based on the above dimensions of inlet and outlet weirs and for the three hole sizes of interest, we get the data of Table 1.

TABLE 1. Active Surface of Sieve Plates.

Hole dia. (in.)	Number of holes per sq. ft of column cross-section area	$\frac{\text{Area of holes}}{\text{Area of column}} \times 100$
$\frac{1}{8}$	915	9.15
$\frac{3}{16}$	416	8.0
$\frac{1}{4}$	230	6.9

Minimum Vapour Rate

As the liquid flows across the plate it is prevented from falling through the perforations by the vapour entering the holes. If the velocity of the vapour through the holes is below a certain minimum value, the liquid is no longer supported on the plate. The minimum vapour velocity depends on the hole diameter, height of clear liquid on the plate and on such properties of the liquid as density, surface tension and viscosity.

Arnold *et al.*,[6] Mayfield *et al.*[4] and Hunt *et al.*[14] have given data on minimum vapour rates for the system air-water. Zenz[7] studied the effect of liquid properties but, unfortunately, has not given any data; he mentions, however, that decreasing the surface tension of the liquid increases the minimum vapour rate.

Hunt *et al.*[14] have also given some data for air and other gases with water and various liquids, but his results indicate that lower vapour rate is required with decreasing surface tension; he also suggests that the air-water data may be used as a conservative basis for design. The data of Arnold and Mayfield for air-water have been correlated in the form:

$$(v\ \rho_G^{\frac{1}{2}})_M = F - 18.8\ (1 - \delta) \qquad \ldots . (1)$$

where v = vapour velocity through hole, ft/sec.,
ρ_G = vapour density, lb./cu. ft,
δ = hole diameter, in.,
and subscript M refers to *minimum* vapour velocity.

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Values of F are shown in Fig. 1 plotted against height of clear liquid (i.e., height of weir plus weir crest); to facilitate the use of Fig. 1, the co-ordinates of the plot are given in the table accompanying Fig. 1.

Froth Height

As the vapour bubbles through the liquid on the plate it creates a froth consisting of bubbles of the vapour in the liquid. It is important to know the height of the froth for two reasons. (a) The height of froth determines, to some extent, the time of contact between the vapour and the liquid, and hence the efficiency of the transfer process. (b) The distance between the top of the froth and the plate above affects the degree of entrainment; hence the greater the froth height, the larger must the plate-spacing be in order to get an adequate froth-free region.

Kamei and Takamatsu[8] have described the effect of vapour velocity on froth height. At low vapour velocity there is a clear liquid layer on the plate surface and the froth floats on the surface. As the velocity is increased the extent of the clear liquid decreases and the height of the froth increases, so that the entire contents of the plate is a mass of froth. The froth height increases with increasing velocity until a certain critical velocity is reached, after which it gradually decreases. At the highest velocity there is splashing of the whole liquid mass. It appears as though at low and medium vapour velocities the liquid is the continuous phase and the vapour the dispersed phase, while at the highest velocity the roles are reversed. Kamei[8, 9, 10] has shown that the highest efficiency and maximum entrainment occur at the vapour velocity which gives the greatest froth height.

Kamei has published several froth-height-vapour velocity curves which show the maximum described. Other workers do not appear to have noticed such a maximum. The reason for this may be because Kamei has done most of his work with columns of small diameter and with very small perforations, while others have worked with columns and hole sizes that are usual in industry, and at their highest vapour velocities they may not have reached the maximum.

It should be possible to calculate foam height from first principles if we make certain assumptions—the chief assumption being that the liquid properties can be ignored. Calderbank[11, 12] has pointed out the interesting fact that at vapour velocities through the perforations that are normal in industrial practice, the bubble-frequency is constant at about 17.5 bubbles a second. If this is so, then with increase in vapour velocity the bubble diameter must increase; van Krevelen and Hoftijzer[13] working with single orifices, have obtained bubble diameters eight to nine times the orifice diameter. In perforated distillation plates the bubble diameter is not likely to exceed the pitch of the holes, as at that diameter bubbles from adjacent holes will touch each other.

Hence, if the bubble frequency is constant and the bubble diameter reaches a maximum value equal to the pitch of the holes, then if we continue to increase the vapour rate, as Calderbank[12] has shown, two things will happen: (i) the bubbles will be in contact with each other as they rise, and (ii) a considerable part of the vapour will "leak" through the chain of bubbles. Therefore, the froth height will not increase proportionately with vapour rate; in fact, under normal distillation conditions, as much as 70 to 80% of the vapour "leaks" out and only about 25% is held in the aerated mass of liquid. If the amount of "leakage" can be predicted then the froth height can be calculated.

Attempts to calculate and correlate the amount of vapour "leakage" were not successful and a direct correlation of froth height was made. Fig. 2 shows a correlation of the froth-height data of Brook *et al.*[16] and West[15] where:

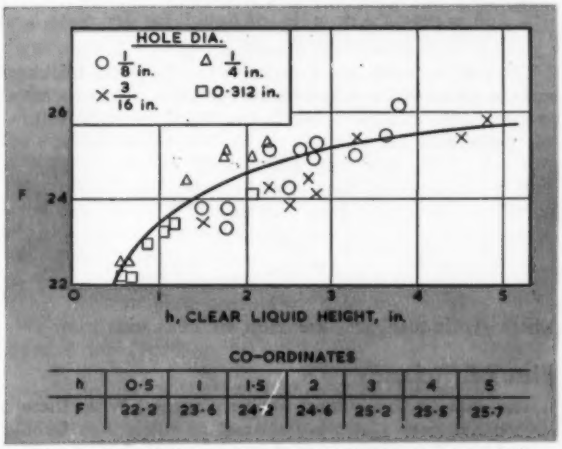
$$\frac{0.1}{h} + \log (z\,\sigma^{\frac{1}{4}}) \text{ is plotted against } v \qquad \ldots . (2)$$

where h = clear liquid height, in.;
z = froth height, in.;
σ = surface tension of liquid, dynes/cm.; and
v = vapour velocity through slot, ft/sec.

The co-ordinates of Fig. 2 are given in Table 2.

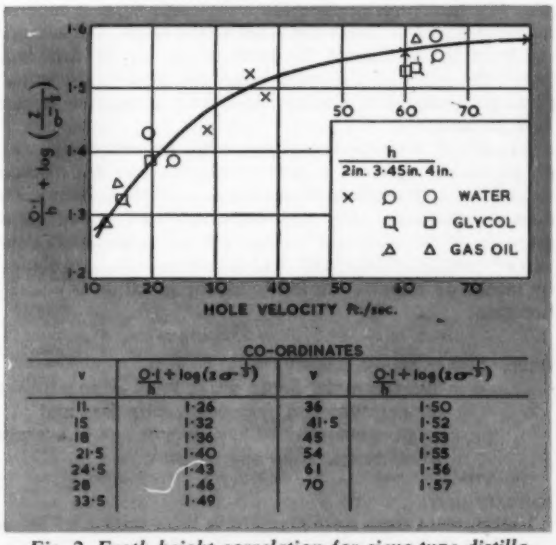
Pressure Drop Through Plate

The pressure drop the vapour suffers as it goes through the plate may be considered as made up of the pressure drop due to flow through the holes (which will be the same as the pressure drop through a dry plate) and the pressure drop due to the head of liquid equal to clear liquid height. When pressure drops of trays with liquid on them are calculated in this way and compared with actual values, it is found that the calculated values are consistently lower. The actual picture is rather more complicated. The liquid on the plate is aerated and its density



h	0·5	1	1·5	2	3	4	5
F	22·2	23·6	24·2	24·6	25·2	25·5	25·7

Fig. 1. Graph for estimating minimum vapour ratio through perforations based upon Equation (1).



v	0·1/h + log(z σ^-¼)	v	0·1/h + log(z σ^-¼)
11	1·26	36	1·50
15	1·32	41·5	1·52
18	1·36	45	1·53
21·5	1·40	54	1·55
24·5	1·43	61	1·56
28	1·46	70	1·57
33·5	1·49		

Fig. 2. Froth height correlation for sieve-type distillation plates used to check tray spacing.

will therefore be less than that of clear liquid; hence, the pressure drop due to liquid head will be less than that calculated on basis of clear liquid height. On the other hand, the vapour has to expend energy to create bubbles, and this energy is manifested as a pressure drop. It would appear that the pressure loss due to bubble formation is greater than the pressure "gain" due to the lower density of aerated liquid and the net result is that the value calculated on the basis of the simple picture is lower than the actual value by about 0.5 in. of water.

Kamei[9] has studied the problem in detail and has given equations which allow one to calculate each of the factors that contribute to the total pressure drop. In practice, these equations are not very helpful, as they require a knowledge of froth height, liquid hold-up, etc., which cannot be predicted accurately. For design purposes it is sufficient to take the total pressure drop as being made up of the "dry-plate" pressure drop plus height of clear liquid plus height of liquid equivalent to 0.5 in. of water.

The dry-plate pressure drop is given by:

$$v^2 = 5.35 \frac{\rho_L}{\rho_G} h \cdot c^2 \qquad \ldots . (3)$$

where v = vapour velocity through hole, ft/sec.;
ρ_L and ρ_G = densities of liquid and vapour, lb/cu. ft;
h = pressure drop, in. of liquid, for dry plate; and
c = orifice coefficient, dimensionless.

The orifice coefficient c depends on the plate thickness and the usual practice is to have the plate thickness equal to the diameter of the hole. On this basis, c has the following values:

For $\frac{1}{8}$-in. hole, $c = 0.72$
$\frac{3}{16}$-in. ,, $c = 0.775$
$\frac{1}{4}$-in. ,, $c = 0.83$

The total pressure drop is then

$$\Delta p = 0.187 \frac{v^2}{c^2} \cdot \frac{\rho_G}{\rho_L} + h + \frac{32.1}{\rho_L} \qquad \ldots . (4)$$

where Δp is total pressure drop, in. of liquid.

Plate Efficiency

The data on this subject are very scanty. What there is shows that sieve plates are at least as efficient as bubble-cap plates. We have seen that in sieve plates under normal operating conditions, the bubbles are in contact with each other and most of the vapour "leaks" through the bubbles. We may therefore imagine the bubbles to form a tube of diameter equal to about the pitch of the holes, and extending from the surface of the plate to the top of the froth layer; the walls of the tube being the liquid. The entire plate may, therefore, be considered as a nest of wetted wall columns.

Bakowski[17] has correlated the efficiency of bubble-cap plates on the basis of a similar concept and his method should be applicable to sieve plates, but the scanty data do not allow Bakowski's equation to be tested. An adequate estimate of the overall efficiency can be made by O'Connell's[18] method. O'Connell had expressed his correlation by means of a curve, but the following equation is equally accurate:

$$E = 51.0 - 32.5 \log \mu \alpha \qquad \ldots . (5)$$

where E = overall efficiency, %;
μ = average molal liquid viscosity at average tower temperature and pressure, centipoise; and
α = relative volatility of key components at average tower temperature and pressure.

Entrainment

Entrainment from sieve plates have been studied by Jones and Pyle,[5] Hunt *et al.*[14] and Brook *et al.*,[15] but so little of the data has been published that a correlation is not possible. Comparison with bubble-caps data shows that, for the same plate spacing and vapour velocity through the free area of the column, the entrainment from bubble-caps is about three times the entrainment from sieve plates. The free area of the tower is defined as the cross-sectional area of the tower minus the area occupied by the downcomer, i.e., the area actually available for vapour flow.

Entrainment data of bubble-cap plates have been correlated[19] by means of the equation:

$$\log E + 2.59 \log S + 0.4 \log \sigma + \log \mu = f\left[(v_c)\left(\frac{\rho_G}{\Delta\rho}\right)^{0.5}\right] \qquad \ldots . (6)$$

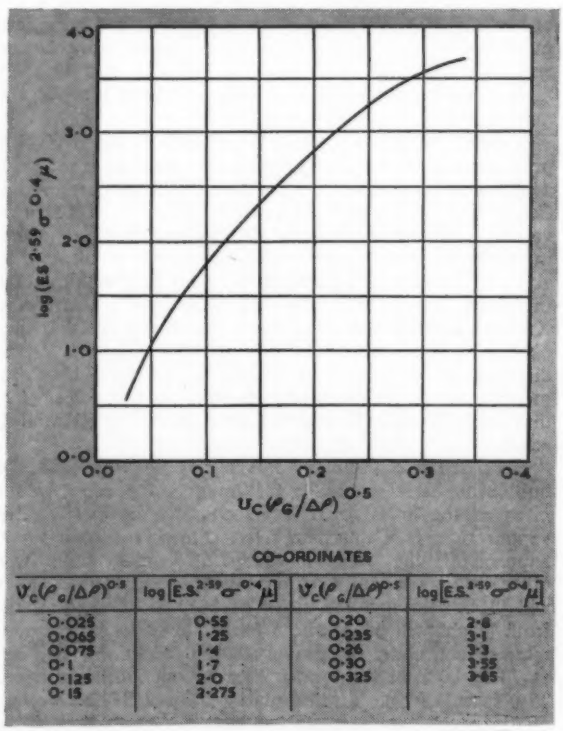
(Equation (6) is shown in Fig. 3 and co-ordinates given.)

where E = entrainment, lb. liquid/(hr) (sq. ft active area of plate);
S = the clear space, in ft, between top of froth layer and the plate above = (Plate spacing $-2 \times$ height of weir);
μ = viscosity of liquid, centipoises;
σ = surface tension of liquid, dynes/cm.;
ρ_G = density of vapour, lb./cu. ft;
ρ_L = density of liquid, lb./cu. ft;
$\Delta\rho = (\rho_L - \rho_G)$; and
v_c = vapour velocity through free area of column, ft/sec.

Design of Sieve Plates

Worked Example

The various correlations suggested in this article will now be used to design a sieve plate to carry out a particular distillation duty. 300 lb. mol/hr of an ethanol-water mixture are to be distilled; the feed is at its boiling point. $x_F = 0.25$; $x_D = 0.80$; $x_w = 0.05$ ethanol; $O/D = 3.0$. The efficiency without entrainment is 75%.



CO-ORDINATES

$V_c(\rho_G/\Delta\rho)^{0.5}$	$\log[E.S.^{2.59}\sigma^{0.4}\mu]$	$V_c(\rho_G/\Delta\rho)^{0.5}$	$\log[E.S.^{2.59}\sigma^{0.4}\mu]$
0·025	0·55	0·20	2·6
0·065	1·25	0·235	3·1
0·075	1·4	0·26	3·3
0·1	1·7	0·30	3·55
0·125	2·0	0·325	3·65
0·15	2·275		

Fig. 3. Entrainment correlation for bubble-cap distillation plates used to estimate plate spacing for a given entrainment.

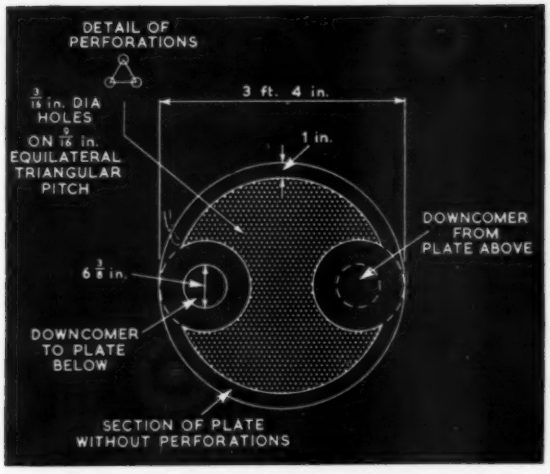

DETAIL OF PERFORATIONS
3/16 in. DIA HOLES ON 5/16 in. EQUILATERAL TRIANGULAR PITCH
3 ft. 4 in.
1 in.
DOWNCOMER FROM PLATE ABOVE
6 3/8 in.
DOWNCOMER TO PLATE BELOW
SECTION OF PLATE WITHOUT PERFORATIONS

Fig. 4. Design evolved in worked example.

A material balance gives $F = 300$ lb. mol/hr; $D = 80$ lb. mol/hr and $W = 220$ lb. mol/hr; also, $V = 320$ lb. mol/hr. As the properties of the liquid and vapour are different at the top and bottom of the column, we should carry out simultaneous calculations for a typical plate in the rectifying section and for a typical plate in the stripping section; if the two designs are similar, an average design may be suitable for the entire column. In this illustration we shall design for a plate in the rectifying section.

Taking a plate on which the liquid has the composition of $x = 0.6$ as typical, we find from the McCabe-Thiele diagram (corrected for 75% efficiency) that the compositions of the vapours entering and leaving the plate are 0.65 and 0.67. The average density of the vapour is 0.08 lb/cu. ft and of the liquid 49.75 lb./cu. ft. The total volume of vapour entering the plate is 147,900 cu. ft/hr, or 41.2 cu. ft/sec. Liquid flow is 240 lb. mol/hr, or 0.047 cu. ft/sec.

As the minimum vapour velocity, froth height and entrainment depend to some extent on the height of weir or clear liquid, we must first decide on the height of weir. There is no information on the effect of height of weir on efficiency, so we must proceed by analogy with bubble-cap plates. Davies[2,3] has recommended a static submergence of 0.5 in. for bubble-caps. We may assume that the distance of travel for a bubble, in terms of clear liquid height, is from the middle of a slot to the surface of the clear liquid; a conventional bubble-cap will have a slot height of 1 in. The weir crest should not be less than 0.25 in., so we shall assume that the weir crest is 0.5 in. The weir height is then $0.5 + 0.5 = 1.0$ in. and the clear liquid height $1.0 + 0.5 = 1.5$ in.

For a hole diameter of $\frac{3}{16}$ in. we get from Equation (1) and Fig. 1 $v_m = 31.5$ ft/sec. For the operating vapour velocity we shall take twice the minimum velocity, or 63 ft/sec. The area of one hole is 0.000192 sq. ft, and we shall require 3400 holes with 0.655 sq. ft total hole area. On the basis of using a chord weir, as previously discussed, the hole area is 8% of the column area. Hence, column area is 8.2 sq. ft, or the diameter is 3.25 ft. With a column of this diameter the holes will come right up to the walls; in order to give strength to the plate we must leave an unperforated margin 1 in. wide. The column diameter then becomes 3 ft 5 in.; and the length of the chord weir will be 30 in. or 2.5 ft.

From the conventional Francis' weir formula, the weir crest over a 2.5-ft-long weir will be 0.38 in. We had assumed a crest of 0.5 in. which will require a weir length of 1.67 ft, or 20 in. A chord weir of this length in a column of 3 ft 5 in. diameter will be very small and awkward and, therefore, the top of a circular downcomer must be used as the weir. The diameter of a circle of 20 in. circumference is 6.37 in.

As we have changed the design of the downcomer, we must recalculate the diameter of the column on a new basis. The pitch of the holes will be $\frac{5}{16}$ in. An equilateral triangle of sides $\frac{5}{16}$ in. and area 0.000953 sq. ft will include half a hole; hence 3400 holes will require a perforated area of 6.48 sq. ft. If the holes are drilled too close to the weir then the flow over the weir will be uneven; it is good practice to have 2 to 3 in. clear distance between the inlet and outlet weirs and the nearest row of holes. As the downcomer weirs are 6.37 in. in diameter, two circles, each of 12 in. diameter, must be allowed for the two weirs and the surrounding blank spaces, i.e., a combined area of 1.57 sq. ft. The total area is, therefore, $6.48 + 1.57 = 8.05$ sq. ft; the column diameter is 40 in., or 3 ft 4 in., including the 1-in. margin all round. Thus the diameters calculated by the two methods are practically the same.

The free area of the column is the cross-sectional area minus the downcomer area, i.e., $8.05 - 0.22 = 7.83$ sq. ft, and the vapour velocity will be $41.2/7.83 = 5.3$ ft/sec. The active area of the plates is 6.48 sq. ft.

The plate spacing must now be calculated. The effect of a reasonable amount of entrainment on distillation efficiency is slight, so that it is best to use Equation (6) to calculate the plate spacing for a predetermined entrainment. We shall assume that we can tolerate 5.0 mol of entrained liquid per 100 mol of vapour. The total entrainment is then 557 lb./hr, or 86 lb/(hr) (sq. ft active area). The equivalent entrainment for a bubble-cap column would be $3 \times 86 = 258$ lb./(hr) (sq. ft).

For 60% boiling ethanol-water mixture: $\sigma = 20.8$ dynes/cm., $\mu = 0.58$ centipoises and $(\rho_G/\Delta\rho)^{0.5} = 0.0401$. Substituting Equation (6), we get, for $v_c = 5.3$ ft/sec.:

$$\log 258 + 2.59 \log S + 0.4 \log 20.8 + \log 0.58 = 2.9$$

S = (Plate spacing $- 2 \times$ weir height) = 14.3 in.

or plate spacing = 16 in.

We must now compare this plate spacing with the froth height. From Fig. 2 we get:

$$\frac{0.1}{h} + \log (Z\sigma^{\frac{1}{4}}) = 1.56, \text{ or } Z = 11.33 \text{ in.}$$

As the plate spacing is 5 in. more than the froth height, there is little danger of froth rising to the plate above.

The pressure drop through one plate can be calculated from Equation (4):

$$\Delta p = 0.187 \frac{(63)^2}{(0.775)^2} \cdot \frac{0.08}{41.2} + 1.5 + \frac{32.1}{41.2}$$

$= 0.24 + 1.5 + 0.78 = 2.52$ in. of liquid, which is satisfactory.

In this series of calculations the liquid-handling capacity of the downcomers has been omitted, as this is a straightforward estimation which can be carried out in the same manner as for bubble-cap plates. Likewise, the design of the inlet weir has been omitted as another detail common to both types of plate, which has been adequately treated by Mayfield *et al.*[4]

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EVAPORATING PLANT IN THE CHEMICAL INDUSTRY

A short description is given of a multiple-effect side-separator type of evaporator. The section on heat transfer shows the range of figures obtained for different liquors and under different conditions

by JOHN BLACK

THE function of evaporating plant as applied to the chemical industry is, in almost all cases, the concentrating of liquors. In fact, it is one of the most important and widely used processes in the industry. The sketch shows a diagrammatic arrangement of a multiple-effect side-separator evaporator. It comprises calandrias with centrifugal separators fitted at the top of each. The mixed liquors and vapours enter the separators tangentially, setting up a centrifugal action and separating out. The vapours pass off while so much of the liquor flows forward to the next effect, the remainder being recirculated to the previous calandria. The evaporators are of the climbing-film type.

The liquor to be evaporated is fed into the evaporator till it rises to a uniform height. It immediately begins to evaporate and give off vapour. The vapour begins to form bubbles, but as its volume steadily increases, with a corresponding high increase in velocity, the liquor attaches itself to the tubes in the form of a uniform film, the vapour forming a centre core, and both pass into the separator through the tangential inlet at high velocity. Because of the centrifugal action produced in the separator, the heavier particles of liquor are separated from the vapour, the former flowing down the sides and the latter passing upwards to the vapour pipes and down to the calandria of the next vessel. A portion of the liquor at the bottom is returned to the evaporator for further circulation, and the balance passed on to feed the succeeding vessels.

Design and Performance

A double-effect evaporator of the side-separator type without a thermocompressor will give an evaporation of about 1.7 lb. water/lb. steam, while with thermocompression, as illustrated in Fig. 1, this figure will be of the order of 2.8 lb. water/lb. steam. The rate of evaporation in this type of plant is governed by liquor densities, temperature differences and the cleanliness of the tubes. As this plant is continuous in operation, the first effect will always contain thin liquor, the thick liquor being handled in the last effect and withdrawn at the required density by an extraction pump. Consequently, heat-transfer coefficients (H.T.C.s) may be of the order of 350 Btu/hr/sq. ft/°F in the first effect, and progressively reducing to around 100 Btu/hr/sq. ft/°F in the last effect. (Note that figures given for heat-transfer rate are typical and can only be found from practice for any specific liquor.)

Where a thermocompressor is fitted to the first effect, it is obvious that a greater amount of heat is transferred through the tubes of this effect than through the surfaces of the later effects; consequently, the surface area in this vessel is proportionately increased. Thermocompressors give the greatest advantage when the steam supply pressure is high and the compression ratio low. Under these conditions a very high entrainment ratio can be obtained.

When an evaporator is manufactured to deal with a liquor of known characteristics, it will be found that the plant will operate very close to the design figures. On the other hand, where a plant has to be designed for a liquor on which there is little available information, safe allowances have to be made for such figures as heat-transfer coefficients, especially in the later effects where concentrated liquor is to be handled. It may also be found on running a plant of this sort that, though the overall temperature difference agrees with the design figure, the intermediate temperature differences vary.

The following figures relate to a double-effect evaporator with thermocompression, concentrating a liquor from 3.5% to 28% solids. The figures used in the design of the plant are compared with actual figures taken on test.

	Design	*Test*
Steam pressure to thermocompressor (psig)	60	60
Vacuum in first calandria (in. Hg.) ...	12	17
Vacuum in first-effect vapour space and second calandria (in. Hg.)	20	21
Vacuum in second-effect vapour space and condenser (in. Hg.)	28.15	27.5
Steam to compressor (lb./hr)	2250	2340
Evaporation (lb./hr)	6100	6310
Lb. vapour/lb. steam	2.71	2.70

It is noticeable that this plant was not operated at its design conditions, though the output and steam consumption are approximately correct. This plant was to handle a

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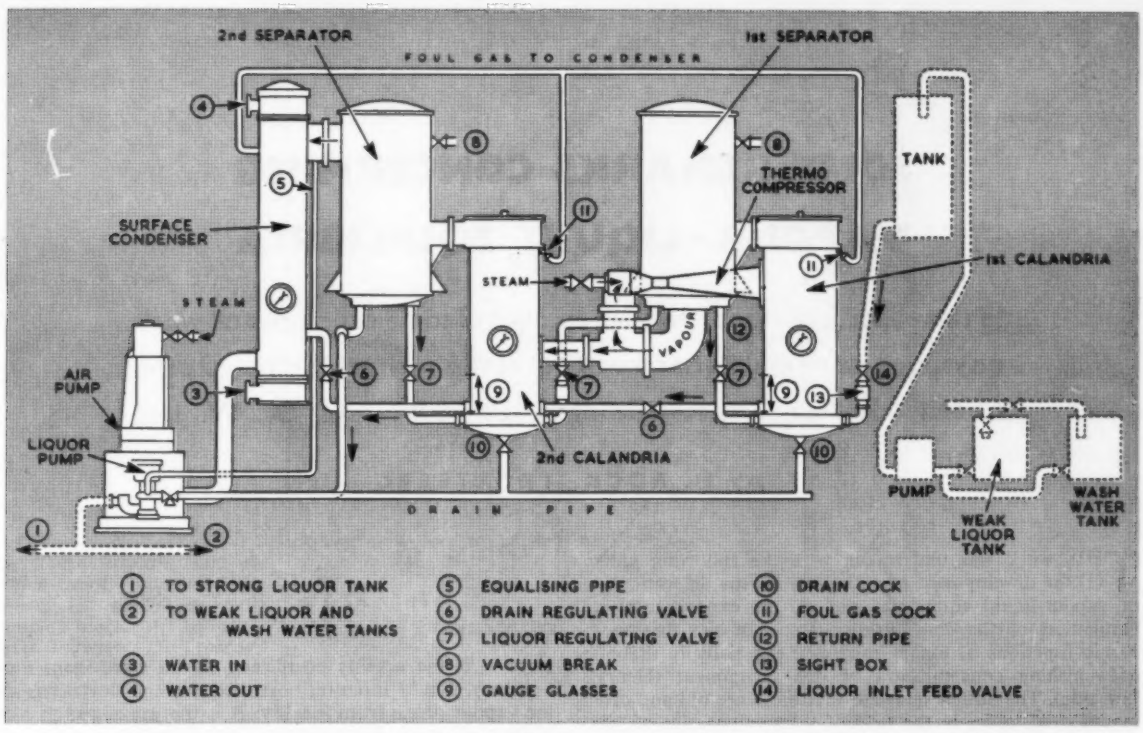

Fig. 1. Diagrammatic arrangement of a double-effect evaporator of the side-separator type. That illustrated is fitted with a thermocompressor and will give an evaporation of the order of 2.8 lb. water/lb. steam.

liquor of somewhat unknown characteristics, and H.T.C.s of around 200 and 60 Btu/hr/sq. ft/°F were used in the design for the first and second effects respectively. From the test the H.T.C. figures came out to approximately 300 and 80 Btu/hr/sq. ft/°F. It should, however, be remembered that with dirty tubes, etc., these figures might well fall, in which case the vacuum would have to be brought nearer to the design figure, thus increasing the overall temperature difference, to obtain the required output.

Materials of Construction

There are a number of factors to be considered in selecting materials for the construction of an evaporator dealing with corrosive chemicals. Obviously, the major consideration is to find a material which will, at least to a large degree, withstand the corrosive action of the liquors or vapours with which it is going to be in contact. Against this must be put the cost of material and its suitability for manufacture and operation in an evaporator. It is not possible here to list the materials suitable for use with different liquors, though copper, stainless steel and aluminium are possibly three of the most used today, when mild steel or cast-iron is unsuitable.

Selection of Plant

The well-known standard method of deciding on the type of evaporator to be bought is based on cost of plant versus operating costs. There are, however, certain other factors governing the selection of a plant which must also be considered. In certain cases where the final concentrated liquor is a slurry, batch-type evaporation is almost essential. An evaporator with a deep conical bottom might then be required for easy discharging.

Certain liquors are sensitive to heat and the boiling temperature must therefore be kept low. This can best be done by thermocompression where the steam may enter the calandria under vacuum. A climbing-film evaporator, due to the high velocity of the liquor up the tubes, is very suitable where a short heating time is desired.

Evaporating Plant Auxiliaries

The two main auxiliaries required by the above evaporators are condensers and vacuum pumps. With surface and jet condensers it is necessary to pump the water from the condenser by means of a wet vacuum pump or condensate extraction pump, whereas with a barometric condenser the water drains down a barometric leg which must be of sufficient length to hold the condenser vacuum. Jet or barometric condensers are considerably cheaper than the surface type and for this type of work are often completely satisfactory. They can be used when it is unimportant if the condenser cooling water mixes with the vapours coming over from the evaporator. If it is desired to keep the cooling water uncontaminated, a surface condenser must be used.

Vacuum pumps are mainly of three types, viz.: Wet air reciprocating piston pumps; dry air reciprocating piston pumps and steam ejectors. The wet air pump, in addition to creating vacuum, also handles the condensate from the condenser. These pumps are usually of the "Edwards" type. Dry air pumps are simply reciprocating air pumps handling only air and are suitable for use with a barometric condenser or surface condenser, but in the latter case a condensate extraction pump would also be necessary. Each of these pumps may be either steam- or motor-driven. The steam ejector air pump is becoming more and more popular in modern vacuum practice. These can be single- or multi-stage depending on the required vacuum and available steam pressure, and with multi-stage pumps extremely high vacuum can now be reached.

The author wishes to thank the directors of Blairs Ltd. for permission to publish this article.

SOME REMARKS CONCERNING VAPOUR-LIQUID EQUILIBRIA

In this paper, the author gives an account of some experimental work on vapour-liquid equilibria carried out at the Institut für physikalische Chemie der Universität Göttingen, Director: Prof. Dr. W. Jost

by H. RÖCK, TROSTBERG

THIS work was undertaken with the following aims: (1) the development of apparatus for the determination of vapour-liquid equilibria; and (2) the experimental investigation of the concentration trend of the thermodynamic functions of binary mixtures, especially in the case of vanishing concentration of one component (Henry's law case). The author is aware that these are old and often investigated topics in the field of thermodynamics of mixtures; nevertheless, it is hoped that the reader will find some new information.

(1) Development of an Apparatus for the Determination of Vapour-liquid Equilibria

Measurements of vapour liquid equilibria might be grouped into two classes:

(a) Determination of partial pressures, which means finding the coexisting mole fractions of the liquid (x_i) and the vapour (y_i) phase at a known temperature T and pressure P.

(b) Measurement of the total pressure, which means finding the pressure P as a function of the mole fraction in the liquid phase x_i at a known temperature T.

I. Partial Pressure Method

The first method is subdivided into isothermal and isobaric measurements, but this makes no great difference in respect of the apparatus used. An excellent review of the evolution of the equilibrium still (Method I) within the last seventy years has been given by Fowler,[1] who described many types of apparatus based on various experimental principles and designed to give accurate measurements. But how is it possible to calculate a numerical value of the reliability of equilibrium measurements? Zawidzki[2] tried to answer this question in 1900 by using the Duhem-Margules equation. The best means for controlling experimental data of this type has been found by Herington.[3] He proposed to apply the following, easily deduced equation to partial pressure measurements:

$$F_T = RT \int_0^1 \ln \frac{\gamma_1}{\gamma_2}\, dx_1,\ T = \text{const.} \qquad \ldots.(1a)$$

Here γ_i is the activity coefficient of the component i of a binary, liquid mixture, corrected for the deviations of the vapour phase from ideality; R is the gas constant; and T the absolute temperature. Using the arguments of thermodynamics, it can be shown[3 and 7] that the value of the integral, extended from $x_1 = 0$ to $x_1 = 1$, should be zero in the case of thermodynamically consistent measurements:

$$F_T = 0 \qquad \ldots.(1b)$$

This criterion of consistency suffers in some instances from the drawback that the measurements must cover the whole concentration range $0 \leqslant x_1 \leqslant 1$. But when experimenting with a new equilibrium still, this disadvantage is of no importance, because the application of Equations (1a) and (1b) will show to the experimenter at once the quality of his measurements and of the functioning of his still. There is no more need of general comment about the inherently good or bad constructional details of new stills, nor is one forced to make comparisons with older

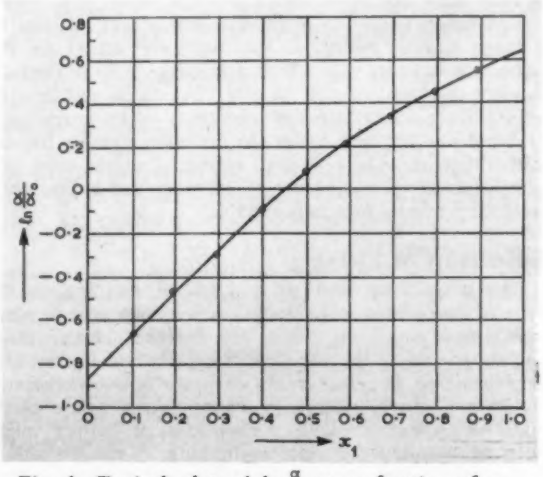

Fig. 1. Typical plot of $\ln \frac{\alpha}{\alpha_0}$ *as a function of* x_1. *System* CH_3COCH_3 (1)/$CHCl_3$ (2) *at* 50°C.[7]

Dr Röck *studied chemistry at T. H. Darmstadt and at the University of Göttingen. He worked with Professor Jost on mixed-phase thermodynamics and separation processes. Recently he wrote a book on "Selected Modern Separation Processes" (including gas-chromatography, thermal diffusion and zone melting) for the purification of organic compounds. He is now with the Suddeutsche Kalkstickstoffwerke, Trostberg/Obb, as a research chemist.*

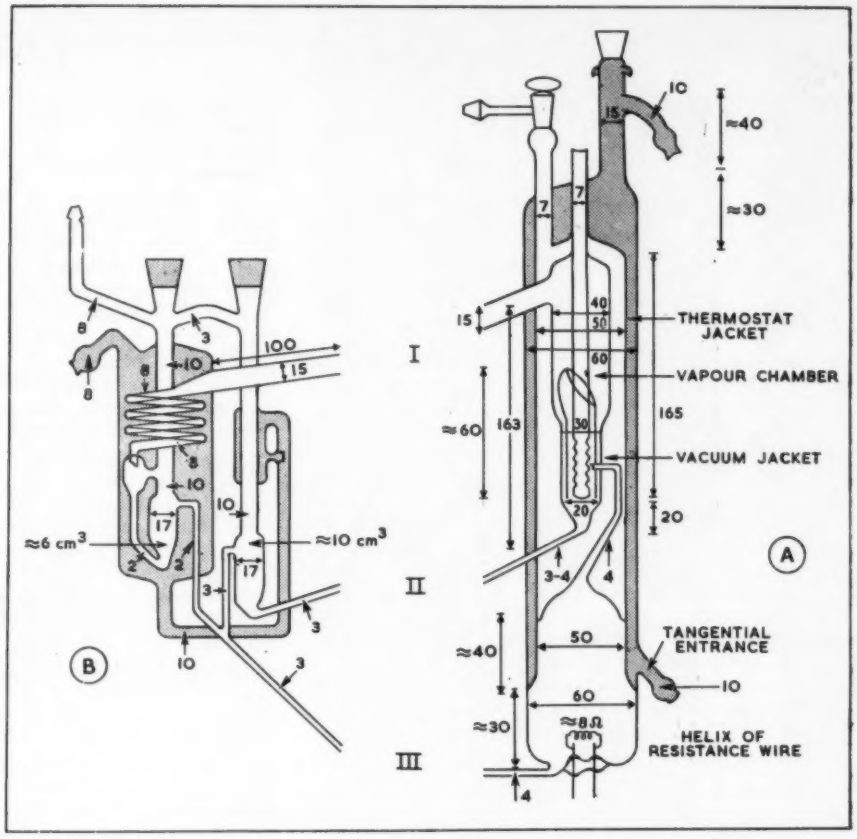

Fig. 2. Equilibrium still: (a) boiler and vapour lift pump; (b) condenser and sample tubes. All dimensions in mm. The roman numbers indicate the proper connections.

measurements on the same binary system, which are claimed to be reliable. The Herington criterion solves all these problems by giving a numerical value of the overall performance of the equilibrium still and of the operator, who might be called an equilibrist in a double sense—both regarding his occupation with equilibrium measurements and his zeal for having $F_T = 0$. So it is possible for a good operator using a primitive still to arrive at consistent results, for example, Zawidzki.[2] But the contrary is also often exemplified, when unskilled or uncritical operators using highly developed stills produce bad equilibrium data. It is suggested that all authors publishing papers concerned with new stills or equilibrium measurements should state the values of F_T according to Equation (1a).

The activity coefficient γ_i is calculated by the following formula:

$$\gamma_i = \frac{P\, y_i}{P_{oi}\, x_i} \cdot e^{\varepsilon_i} \qquad \ldots . (2)$$

where P_{oi} is the vapour pressure of the pure substance i and e^{ε_i} is a term resulting from the pressure-dependent part of the chemical potentials. Then

$$ln \frac{\gamma_1}{\gamma_2} = ln \frac{y_1\, x_2}{x_1\, y_2} - ln \frac{P_{01}}{P_{02}} + \varepsilon_1 - \varepsilon_2$$

and introducing the relative volatility α and the vapour pressure ratio α_0:

$$ln \frac{\gamma_1}{\gamma_2} = ln\, \alpha - ln\, \alpha_0 + \varepsilon_1 - \varepsilon_2 \qquad \ldots . (3)$$

The contribution of the difference $(\varepsilon_1 - \varepsilon_2)$ is, in most cases, small but must be considered in the case of exact measurements. Because usually there are no direct measurements of the second virial coefficient of the vapours, the way of calculating ε_i should be stated when presenting values of F_T.

$$F_T = RT \int_0^1 ln \frac{\alpha}{\alpha_0}\, dx_1 + RT \int_0^1 (\varepsilon_1 - \varepsilon_2)\, dx_1 \qquad \ldots . (4)$$

This paper uses the following simple way for evaluating ε_i:

$$B_i = 0.0867 \frac{RT_{ci}}{P_{ci}} - 0.4278 \frac{RT_{ci}^{2.5}}{P_{ci}\, T^{1.5}} \qquad \ldots . (5)$$

$$\varepsilon_i = \frac{(B_i - V_{oi})\,(P - P_{oi})}{RT} \qquad \ldots . (6)$$

Here B_i is the second virial coefficient, calculated according to Redlich[21] with the critical values T_{ci}, P_{ci}; and V_{oi} is the molar volume of the pure liquid substance i. Equation (6) is only an approximation. The integral F_T can now be evaluated by using the experimental values x_i, y_i, P_{oi}, P and T.

The author considers isothermic measurements for the best way to show the reliability of an equilibrium still. But, of course, the Herington criterion can also be applied to isobaric measurements.[7]

$$F_p = \int_0^1 \left\{ RT\, ln \frac{\gamma_1}{\gamma_2} - \Delta \bar{S}^E \left(\frac{dT}{dx_1} \right)_{b.p.} \right\} dx_1,\ P = \text{const.} \qquad \ldots . (7a)$$

with the analogous condition of

$$F_P = 0 \qquad \ldots . (7b)$$

for thermodynamically consistent measurements. In Equation (7a), the temperature T varies with x_1 and $(dT/dx_1)_{b.p.}$ is the first derivative of the boiling point curve $T_{b.p.} = f(x_1)$. $\Delta \bar{S}^E$ is the integral molar excess

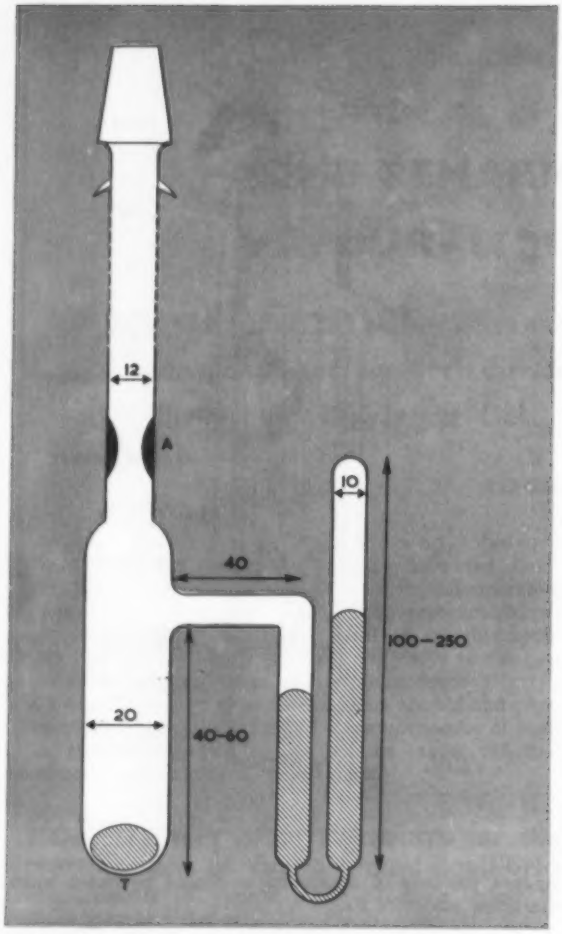

Fig. 3. Sample vessel and manometer. A *constriction,* T *drop of mercury for stirring the liquid by shaking. Dimensions in mm.*

entropy of mixing, and because of the fact that $\Delta\bar{S}^E$ is usually unknown or not exactly predictable, the evaluation of F_P is much more uncertain than of F_T. One can arrive at experimental values of $\Delta\bar{S}^E$ by doing isothermic measurements at two different temperatures.

Integration of $ln\ \frac{\gamma_1}{\gamma_2}\ dx_1$ or of the other functions is done graphically. The following abbreviations are used:

$$K = \int_0^1 RT\,(\varepsilon_1 - \varepsilon_2)\,dx_1$$

$$i_P = \int_0^1 \Delta\bar{S}^E \left(\frac{dT}{dx_1}\right)_{b.p} dx_1$$

Table 1 contains values of F_T, F_P and of the different terms that sum up to F_T or F_P, calculated according to experiments described in the literature (see also Fig. 1).

The measurements of Kretschmer and Wiebe[4 and 5] appear to be the best ones, indicating good working of their still. This still had the special feature of a short filled column, in which there was parallel flow of the liquid and vapour stream, thus ensuring attainment of equilibrium between the two phases.

If rather good measurements are tested by applying Equation (4), great care must be taken to evaluate $(\varepsilon_1 - \varepsilon_2)$ because this term will then be responsible for the remaining uncertainty. The calculation of ε_i according to Equations (5) and (6) can be in error up to $\pm 100\%$ and are usually not better than $\pm 20\%$.

The equilibrium still devised by Röck and Sieg[6] is of the usual recirculating type and incorporates a Cottrell pump; Fig. 2 shows the apparatus. Special care was taken to avoid partial condensation of the vapours leaving the Cottrell pump. The vapour chamber is surrounded by a vacuum jacket, the outside wall of the jacket being thermostatted by a circulating liquid. The still is heated by an external coil of resistance wire, while the internal coil produces the vapour bubbles which efficiently stir the liquid in the still pot.

The pump tube lifts a vapour-liquid mixture and discharges it on to the thermometer well. Then the vapour and liquid separate, the vapour passing through the vapour chamber to the condenser and vapour trap, while the liquid drains off the thermometer well and the splash shield, passes through the liquid trap and returns to the still. The liquid circulation is greater than the vapour circulation by a factor of about 10^3 to 10^4. Sampling is effected through the sampling tubes with pipettes, the vaporisation losses being negligible by virtue of the great sample volume (10 ml). At no point of the apparatus is there contact of liquid or vapour with stoppers or cocks, thereby avoiding contamination of the mixtures with grease. The equilibrium still was tested by the procedure described above [Equations (4), (5) and (6)]. Acetone/chloroform was the binary test mixture; measurements were carried out at several temperatures and covered the whole concentration range by using values of x_1 respectively close to 0.1, 0.2, 0.3 . . . 0.9 and 0.05 and 0.95. Table 2 gives the results of this study,[7] which are thermodynamically consistent within the limits of acurcacy.

The excess free enthalpy of mixing $\Delta\bar{G}^E$ for this binary system has been approximated by the function:[20 and 7]

$$\Delta\bar{G}^E = Bx_1x_2\,(a_0 + a_1x + a_2x^2)$$

$$x = 2x_1 - 1 = x_1 - x_2$$

TABLE 1—Values for the Consistency-Integrals of Different Measurements

Binary System	T or P	F_T cal/mole	F_P cal/mole	K cal/mole	i_P cal/mole
$CHCl_3/C_2H_5OH$[14]	35°C	−3.3		+4.6	
	45°C	−4.9		+5.2	
	55°C	−8.6		+6.4	
C_6H_6/n-C_7H_{16}[16]	80°C	−33.7		+11.8	
C_2H_5OH/Toluene[5]	35°C	−0.8		+6.3	
$C_6H_6/C_6H_5NH_2$[17]	70°C	−81			
C_6H_6/C_6H_5Br[17]	70°C	−139			
C_6H_6/n-C_7H_{16}[18]	760 mm Hg		−10.8	+12.3	−1.8
$CH_3COCH_3/CHCl_3$[19]	20°C	−43			

TABLE 2—Values for the Consistency Integral of Measurements on the System CH_3COCH_3 (1)/$CHCl_3$ (2). The a's are Constants of the Development for ΔG^E

T, °C	F_T cal/mole	K cal/mole	a_0	a_1	a_2
15	−2.5	+0.5	1.134	−0.193	−0.143
20	−6.0	+0.8	1.080	−0.179	−0.138
30	−0.6	+1.1	1.028	−0.149	−0.154
35	+0.1	+1.3	0.990	−0.142	−0.152
40	−1.1	+1.6	0.957	−0.133	−0.160
45	−1.2	+1.9	—	—	—
50	+1.0	+2.2	0.893	−0.133	−0.126
55	−1.5	+2.6	0.859	−0.128	−0.133

where B has been chosen to be the temperature independent. Values of the activity coefficients or of their ratio are easily derived.

$$RT\ln\gamma_1 = \Delta\bar{G}^E + x_2\frac{\delta\Delta\bar{G}^E}{\delta x_1} \qquad RT\ln\gamma_2 = \Delta\bar{G}^E - x_1\frac{\delta\Delta\bar{G}^E}{\delta x_1}$$

$$\ln\frac{\gamma_1}{\gamma_2} = \frac{1}{RT}\frac{\delta\Delta\bar{G}^E}{\delta x_1} = \tfrac{1}{2}(a_1 + 2(a_2 - a_0)x - 3\,a_1x^2 - 4a_2x^3)$$

By using Equation (3), the relative volatility α can be calculated.

II. Total Pressure Method

This method was used to investigate the concentration dependency of the activity coefficient γ_1 of cyclohexane (index 1) in aniline (index 2) at low concentrations of cyclohexane.[8] γ_1 was calculated by

$$\gamma_1 = \frac{P - p_{02}\,x_2}{p_{01}\,x_1} \qquad \ldots.(8)$$

which is a simplified and specialised form of Equation (2). The method and Equation (8) were developed solely to investigate the above-mentioned special case. Fig. 3 depicts the sample vessel and manometer.

The vessel was connected to a vacuum manifold by the ground-glass joint. Samples of cyclohexane and aniline were degassed separately and the degasification process was controlled by means of a McLeod vacuum gauge. A certain amount of aniline was then distilled into the sample vessel at room temperature by cooling the vessel with solid CO_2/CH_3OH. Next, the quantity of cyclohexane to be added was determined by a gas volumetric procedure. The cyclohexane gas was condensed into the aniline by cooling with liquid air, then the vessel was sealed at the constriction. For measuring the total pressure P, the vessel was totally immersed in a water thermostat and pressure readings were taken with the aid of a cathetometer at temperatures from 15 to 90°C. After the completion of a run, the vessel was weighed and then opened. The liquid mixture was removed and the vessel reweighed to give the total weight of the mixture. By means of this and the known amount of cyclohexane, the mole fraction x_1 can be calculated. The solvent nature of cyclohexane prohibited the use of greased stopcocks or ground-glass joints at places of high cyclohexane pressures; mercury seals and glass-to-glass connections were used. These difficulties did not arise when the activity coefficients of water in aniline were measured at small mole fractions of water with an essentially similar method.[9]

In addition to determining the vapour pressure P above the mixtures, the vapour pressures of the pure substances also were measured. The aniline vapour pressure in the temperature region from 0 to 60°C was investigated by three different methods[10]:

(1) With a vessel, manometer and method like that illustrated in Fig. 3 and described above.

(2) With a special manometer, using aniline as a manometer liquid. Fig. 4(a) shows this manometer. The assembly was connected to a vacuum system. Carefully degassed aniline was distilled into the manometer legs by immersing them into an ice water bath. After filling each leg half-way up, the manometer proper was sealed at the prefabricated constriction. By circulating ice water (t_o) through the left leg and water of a given higher temperature t through the right leg, the height difference h between the two menisci, the height H [see Fig. 4(a)] and the densities ρ_t in the hot leg and ρ_{to} in the ice-cold leg allow the calculation of the vapour pressure, if the aniline vapour pressure at 0°C is known.

$$P_t = P_{to} + 0.7335\,[h\rho_o + H(\rho_o - \rho_t)],\ mm\ Hg \qquad \ldots.(9)$$

(3) The third method is to measure P_{to}. A six-litre glass flask was evacuated and connected with a vessel containing degassed aniline at temperatures t between −5.9° and +20°C; the temperature of the flask was well above 24°C [see Fig. 4(b)]. After a period of 30 minutes for the attainment of equilibrium, the stopcock at the flask was closed, the whole assembly disconnected and the amount of aniline in the flask analytically determined by titrating with tribromoaniline. Using the ideal gas law

$$P_t = \frac{n\,RT}{V}$$

the vapour pressure P_t was calculated from the mole number of aniline n and the temperature T and volume V of the flask.

The regions of measurement for these three methods overlapped to a certain extent, providing an easy control for the different methods.

TABLE 3—Vapour Pressures of Aniline: t in °C, P in mm Hg.

Method 2		Method 1		Method 3	
t	P	t	P	t	P
30.2	0.95	35.8	1.41	−5.9	0.056
35.0	1.32	40.3	1.85	0.0	0.096
37.6	1.56	45.7	2.64	9.3	0.21
40.1	1.84	50.1	3.42	12.9	0.27
42.5	2.12	60.8	6.59	17.4	0.38
45.1	2.49	65.0	8.16	19.9	0.48
45.7	2.58	70.8	11.2		
50.6	3.50	80.1	17.9		
56.0	4.80				
60.0	6.44				

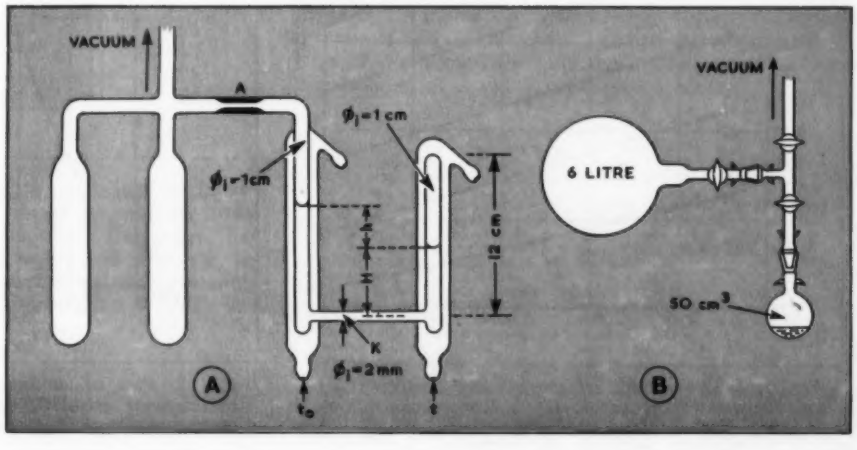

Fig. 4(a). Vapour pressure manometer. A constriction, K capillary. Fig. 4(b). Apparatus for the determination of low aniline vapour pressures.

(2) Concentration Trends of Thermodynamic Functions

This section presents the results of some investigations made with the pieces of apparatus described in Section 1. Table 3 gives the vapour pressures of pure aniline.[10] The average accuracy is ±2%.

An interpolation function between 0° and 80°C is:

$$ln_{10} P = 8.997 - \frac{2.728}{T}$$

These aniline vapour pressures were used when the activity coefficients of cyclohexane in aniline were calculated according to Equation (8). These determinations[8] were made in the concentration range of $x_1 = 0.05$ to $x_1 = 0.005$, corresponding to 5 to 0.5 mole % cyclohexane in aniline. It was considered of interest to investigate if there was a tendency for the log γ_1 *vs.* x_1 curve to flatten out when approaching zero concentration of cyclohexane. Earlier investigators[11] claimed to have indications of

$$lim\ x_1 \rightarrow 0 \frac{\delta\ ln\ \gamma_1}{\delta\ x_1} = 0 \qquad \ldots . (10)$$

Now it is impossible to do exact measurements at concentrations $x_1 \rightarrow 0$. The uncertainty of the experimental value of log γ_1 is proportional to $(x_1)^{-1}$, and, accordingly, the uncertainty of the derivative is proportional to $(x_1)^{-2}$. This situation severely limits the possibility of an experimental answer to the above question. Nevertheless, the experiments were made and showed that, within the limits of accuracy, there is no phenomenological reason for, or possibility of, arriving at Equation (8). The only interpolation curve that might be drawn through the experimental points between 5 and 0.5 mole % without overstressing certain points is linear (see Fig. 5).

The accuracy between 1 and 5 mole % is practically constant, and on the average ±1% of γ_1; at 0.5 mole % the accuracy is only ±3%. What might happen to the curve in the range from 0.5 to 0 mole % is outside the scope of this work, and constitutes a question of statistical thermodynamics.

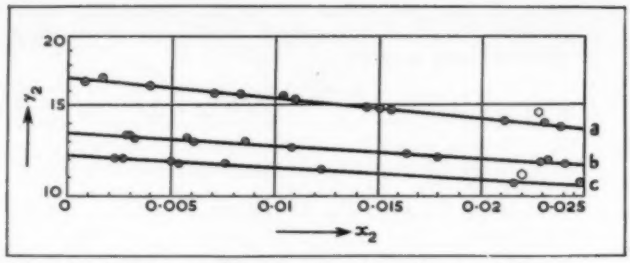

Fig. 6. Activity coefficients of aniline (2) in different hydrocarbons: (a) cyclohexane 40°C, (b) n-heptane 51.5°C, (c) methylcyclohexane 51.5°C. Plotted on a logarithmic scale vs. mole fraction of aniline.

The equilibrium still described in Section 1 was used to investigate the same and other binary systems on the other side of the concentration range, namely, at aniline concentrations from 0.2 to 2.5 mole % in cyclohexane, n-heptane and methylcyclohexane at 40°C.[6] The samples were analysed by weighing, extracting the aniline with aqueous sulphuric acid from the organic phase and titrating the aniline as tribromoaniline. The accuracy is about ±3% on the average, and within this limit the experimental points agree well with a linear interpolation (see Fig. 6).

The validity of the measurements on the system cyclohexane/aniline was checked in a special way,[6] simultaneously giving a check as to the effective functioning of the still. The activity coefficients of aniline γ_2 in cyclo-

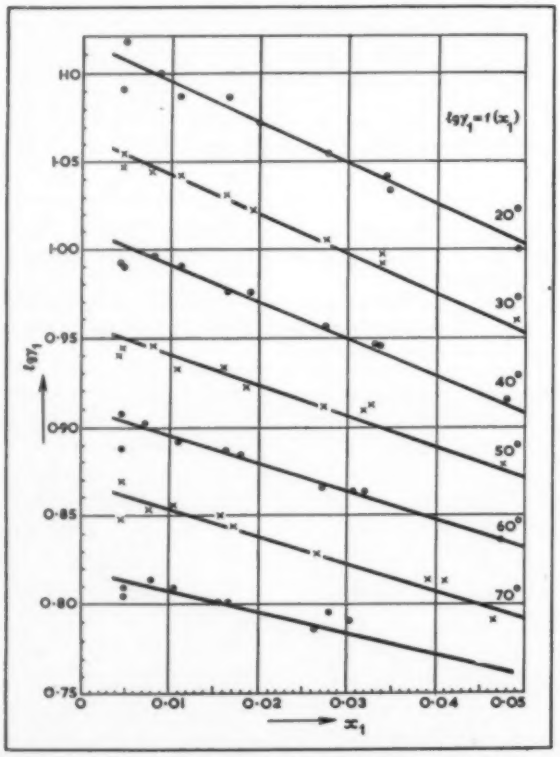

Fig. 5. Measurements of the activity coefficient of cyclohexane (1) in aniline (2) at low concentrations of cyclohexane.

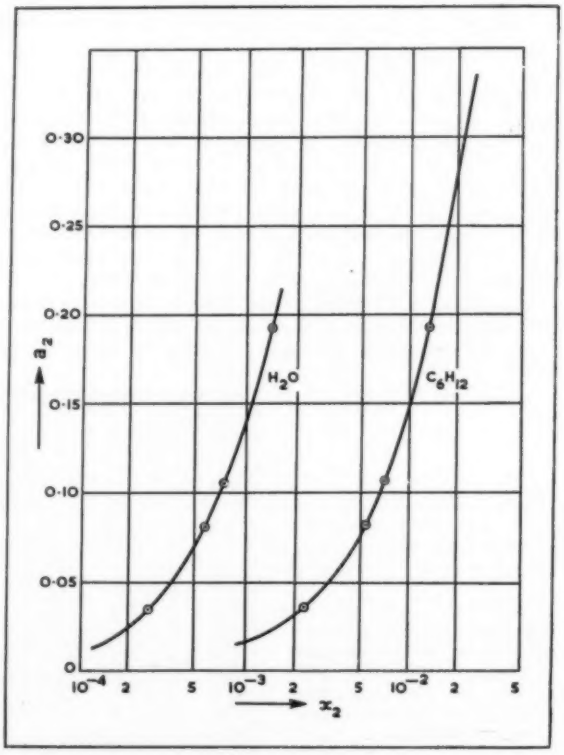

Fig. 7. Plot of aniline activities in water and in cyclohexane at 40°C; x_2= mole fraction of aniline in either of the two phases.

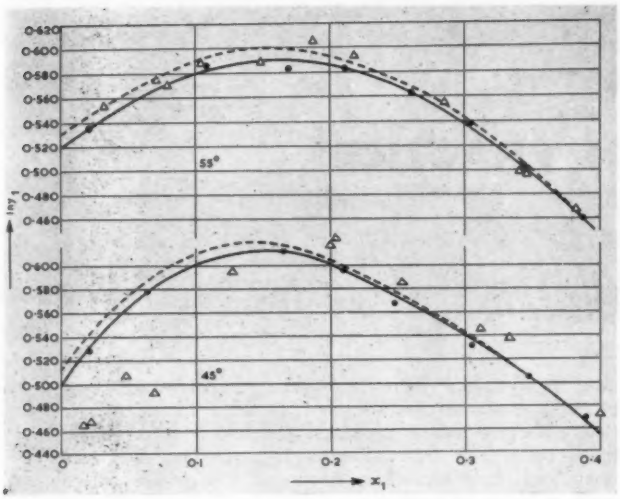

Fig. 8. Plot of natural logarithm of the activity coefficients of $CHCl_3$ (1) in mixtures with C_2H_5OH (2) vs. mole fraction of $CHCl_3$. △ Scatchard's values, ● author's measurements; both not corrected for deviations from the ideal gas law. Curve for author's uncorrected ——— and corrected - - - - measurements. Temperature 45° and 55°C.

hexane and in water were determined using the same equilibrium still. The γ_2 values in water were about 133 in the concentration range from 0.01 to 0.1 mole % aniline at 40°C. Multiplying γ_2 with x_2 gives the activity $a_2 = \gamma_2 x_2$. The aniline activity a_2 in the cyclohexane phase and in the water phase are plotted as functions of the mole fraction of aniline x_2 (see Fig. 7).

Horizontal lines on this graph intersect the curves $(a_2)_{H2O}$ and $(a_2)_{C6H12}$ at points, which represent concentrations of aniline in both phases, these phases being in partition equilibrium. If one now has directly measured the partition equilibrium (or partition coefficients), the values for the concentration in the one phase must fall upon the one activity curve if the value for the concentration in the other phase is pinned down to the other activity curve. This has been done in Fig. 7, as shown by the encircled points. The measured partition coefficients are given in Table 4.

TABLE 4—Partition Coefficients K of Aniline between Cyclohexane and Water

$(x_2)C_6H_{12}$	$(x_2)H_2O$	K
0.000728	0.000085	8.60
0.00234	0.000269	8.70
0.00535	0.000598	8.95
0.00680	0.000751	9.05
0.0135	0.00143	9.44
0.0308	0.00297	10.4
0.0330	0.00314	10.5

An expression for the partition coefficient is derived by the following argument. If the water and the cyclohexane phase are effectively insoluble in each other, then the activities of aniline in the water and in the cyclohexane phase should be the same in the case of equilibrium:

$$(a_2)_{H_2O} = (\gamma_2)_{H_2O}(x_2)_{H_2O}$$

$$(a_2)_{C_6H_6} = (\gamma_2)_{C_6H_{12}}(x_2)_{C_6H_{12}}$$

$$K = \frac{(x_2)_{C_6H_{12}}}{(x_2)_{H_2O}} = \frac{(\gamma_2)_{H_2O}}{(\gamma_2)_{C_6H_{12}}} \qquad \ldots.(11)$$

The concentration dependence of K is marked in spite of the low concentrations. This fact must be attributed mainly to the variation of $(\gamma_2)_{C6H12}$ with concentration, as is shown by the measurements (see Fig. 6). The concentration dependence at low concentrations of γ_i or K is an issue of considerable interest to chemical engineers. Usually the approximation made for the partial pressure of a component i above a diluted solution is:

$$P_i = k_i\, x_i,\ T = \text{const.} \qquad \ldots.(12a)$$

where k_i is Henry's law constant. Comparison with the thermodynamically more exact expression

$$P_i = P_{oi}\ \gamma_i\ x_i,\ T = \text{const.} \qquad \ldots.(12b)$$

yields

$$k_i = P_{oi}\ \gamma_i,\ T = const. \qquad \ldots.(12c)$$

Now when k_i should be constant, then γ_i must be constant (P_{oi} being constant by definition). As this article has shown, there exists for the systems cited a strong dependence of γ_i on concentration even at so low a concentration as 1 mole %. The conclusion is that k_i is usually not a constant, but varies with γ_i according to Equation (12c). Nevertheless, k_i=const. will (and must because of the otherwise inherent difficulties of the calculations where Equation (12) enters) be a good approximation, if one takes an average value of $k_i = P_{oi}\ \gamma_i$ within the considered concentration range.

The same argument applies to the relative volatility α

$$\alpha = \alpha_o \frac{\gamma_1}{\gamma_2}.$$

When $x_2 \longrightarrow 0$, then $\gamma_1 \longrightarrow 1$ and $\frac{d \ln \gamma_1}{d x_1} \longrightarrow 0$ (Raoult's law for component 1). But

$$\frac{d \ln \gamma_2}{d x_2} \neq 0 \text{ for } x_2 \longrightarrow 0$$

and accordingly α is dependent upon concentration even at concentrations of 1 mole % of component 2. This fact is of importance for the separation of pure substances from minor impurities by distillation. For the sake of simplicity one will, and must, take an average value when doing process calculations. Gilmont and Othmer[13] have collected equilibrium data for 110 binary isothermal systems; on reviewing this material, one cannot find a single system where a horizontal tangent of the log α *vs.* x_1 curve might be extrapolated for one or the other concentration limit, which would correspond to a constant α for vanishing concentrations.

The binary system chloroform/ethanol has a most interesting peculiarity. There exists an inflection point on the $\triangle \overline{G}^E$ curve, corresponding to a maximum in the $ln \frac{\gamma_1}{\gamma_2}$ curve and to a maximum or minimum in the $ln\ \gamma_i$ curves. This curious behaviour was first disclosed by Scatchard and Raymond.[14] Their measurements were confirmed by the author's own work.[15] Fig. 8 shows the results in terms of $ln\ \gamma_i$ *vs.* x_i curves. This system is, to the knowledge of the author, the only one exhibiting curves with an extremum in α and is considered a rarity.

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HIGH VACUUM PRACTICE

An account of vacuum techniques described in a recent paper given to the Institution of Mechanical Engineers is given below

THERE can be little doubt that the last decade has witnessed a number of noteworthy advances in high-vacuum technique. During this period new types of pump and new methods of measuring high vacua have made their début. Valves, pipe-lines and jointing methods have been the subject of new designs, and some innovations in leak hunting methods have appeared. It is a curious fact, however, that few papers have been given on such topics by the various learned societies during the past few years. The chemical engineering literature has usually focused attention upon pumps for high vacua, although an exception to this statement is provided by a paper given by Griffiths some years ago.[1]

Some of these topics have been dealt with in some detail in a recent paper given by Kronberger,[2] who discusses a number of leak testing and fabrication methods employed on the huge vacuum system of the diffusion plant of the U.K.A.E.A. plant at Capenhurst. In this paper, which is not claimed to be a review of the most modern techniques, the author distinguishes two main uses for high vacua—one for processes and the other as a testing method for system tightness irrespective of operating pressure. The author considers that the usefulness of this latter practice is not as widely appreciated as it deserves to be.

The Capenhurst diffusion plant is cited as an outstanding example of a high-vacuum system, as it contains not only hundreds of miles of pipework but some hundred thousand joints and ten thousand valves as well. One important reason for vacuum tightness in this plant is the necessity to prevent decomposition of the process gas, UF_6, which would react with the moisture of inleaking air to form corrosive HF and a fine powder, UO_2F_2, which would plug various other components in the system. Other parts of this plant operating above atmospheric pressure, in the interests of health and safety, likewise require complete freedom from leakage. Methods of leak hunting had therefore to be developed, and some of these are described in the paper.

One method employed descends from one familiar to most high-vacuum engineers, i.e., the directing of a stream of hydrogen upon the exterior of a part of a system and noting the response of a vacuum gauge to such treatment. In this case (Fig. 1) a calibrated hydrogen leak 2×10^{-2} lusecs* was incorporated in the circuit. The reading of the vacuum gauge under these conditions was noted and the leak isolated. The equipment under test was then placed in an envelope of hydrogen and connected to the test circuit. The reading obtained was then compared with that obtained by means of the calibrated leak. This particular procedure has the advantage of avoiding the need to clean the equipment under test. With very dirty objects, however, liquid nitrogen or solid CO_2 traps should be fitted to prevent contamination of the pumping fluids.

A number of methods of leak-seeking were indicated by the author as well as by contributors to the discussion. The method most favoured by Kronberger was the charcoal-Pirani method (Fig. 1), because it combines cheapness and rapidity with a reasonable degree of sensitivity.

In the paper and in the ensuing discussion a number of other methods were considered, including those dependent upon the isolation-pressure rise and the mass spectrometer. The merits of the hydrogen-palladium and the differential Pirani methods were also discussed and a brief mention was made of a new method of leak detection employing a Katharometer.

The isolation-pressure rise method, although the most direct of all methods, is unfortunately the slowest. The system to be tested has to be out-gassed until the evolution of gases stops. Cold traps are used to reduce the amount of condensable gases, and the progress of out-gassing has to be judged by comparing the rates of pressure rise with and without the traps. The presence of a leak is shown by a rise in pressure and the leak is located by surrounding the suspected part with hydrogen. If a leak is present it will be indicated by an increased rate of pressure rise on account of the greater diffusivity of hydrogen com-

* A flow of 1 litre of gas at a pressure of 1 micron per second is known as a lusec.

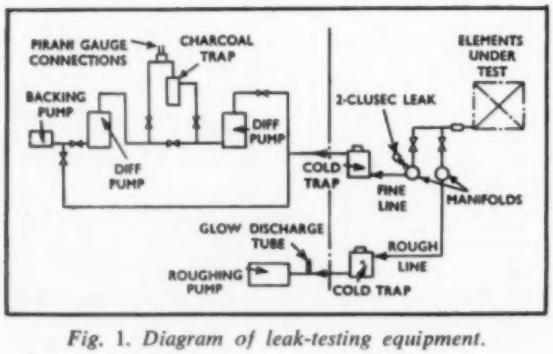

Fig. 1. Diagram of leak-testing equipment.

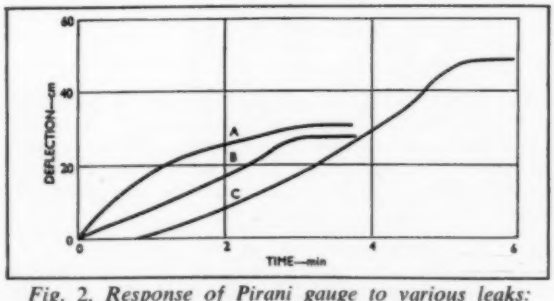

Fig. 2. Response of Pirani gauge to various leaks: (a) bellows 1.1×10^{-2} $l\mu/s$; (b) standard 10^{-2} $l\mu/s$; (c) compound-covered solder leak 1.9×10^{-2} $l\mu/s$.

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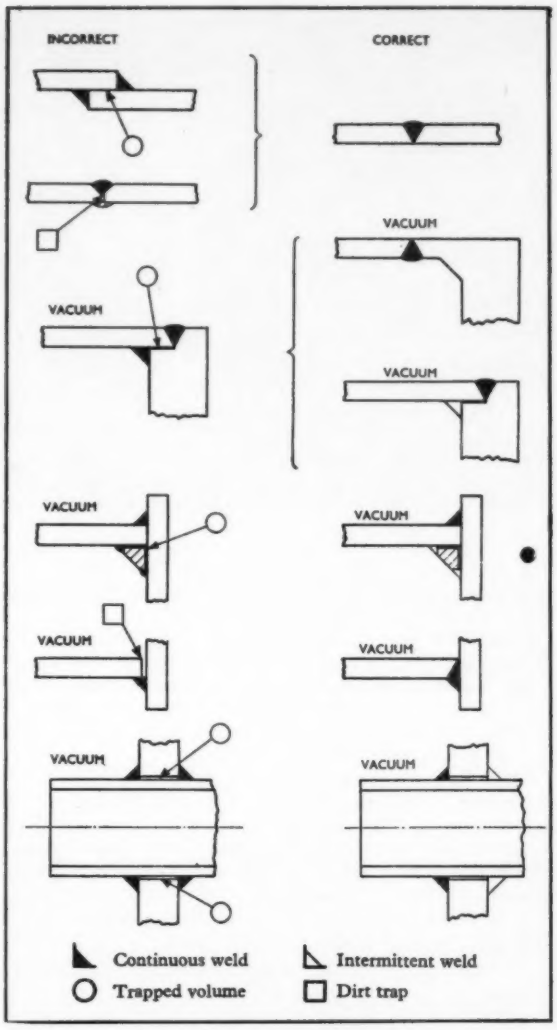

Fig. 3. Welding of vacuum equipment: examples of good and bad practice.

pared with air and sometimes through the greater sensitivity of the gauge to hydrogen.

The method is useful for testing large pieces of equipment; for instance, large vessels which have, in any case, to be degassed. In these circumstances delay can be tolerated and the slowness of the method is not a serious disadvantage. Once the presence of a leak is shown by means of this test, the actual leak may be located by the charcoal-Pirani test. One procedure described in the discussion for testing welds is to cover the run with a strip of balloon fabric, which is then filled with hydrogen. The use of large volumes of hydrogen is thereby avoided.

The mass spectrometer method is growing, but its field, through the high costs of the instrument, is restricted solely to testing a large number of components, such as valves, comparatively quickly. This method has the advantage of enabling testing to take place while out-gassing is proceeding. The spectrometer is, of course, a highly sensitive piece of equipment. Some instruments display the spectrum of gases on a cathode-ray screen, and if the probe gas is brought near a leak the growth of the appropriate mass peak can be seen on the screen. In other instruments, the strength of the signal may be indicated on a meter or it may be made to give an audible signal. Mass spectrometers capable of testing 13,000 pieces of equipment a year to a standard of 10^{-4} lusecs and others handling 1500 components a year to a sensitivity of 10^{-6} lusecs were mentioned in the discussion. The probe gas need not be helium, as was sometimes supposed, but could be coal gas, although methane is better.

In the differential Pirani-gauge† method the pressure-indicating gauges discriminate between the probe gas and the other gases in the system under test. Two gauges are used—one detects the tracer gas, whereas the other is the reference instrument and has fitted upstream an absorber for the search gas. In one version CO_2 can be used as the tracer and calcium hydroxide as the absorbent. Sensitivity is of the order of 10^{-2} lusecs, but the weakness of the

† The Pirani gauge is based on the relationship between the thermal conductivity of a gas and its pressure. Thus $k = K_p$, where K is a constant, k is the thermal conductivity and p is its pressure.

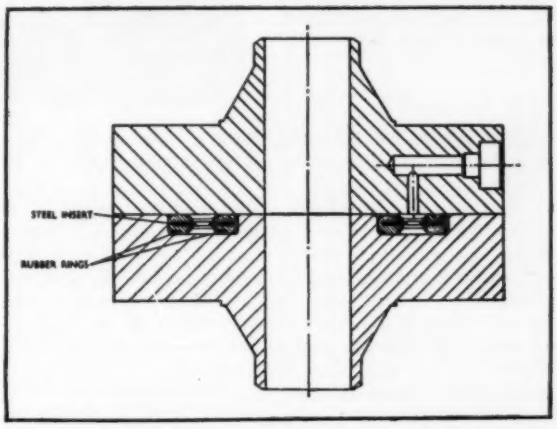

Fig. 4. Flange with interspace joint.

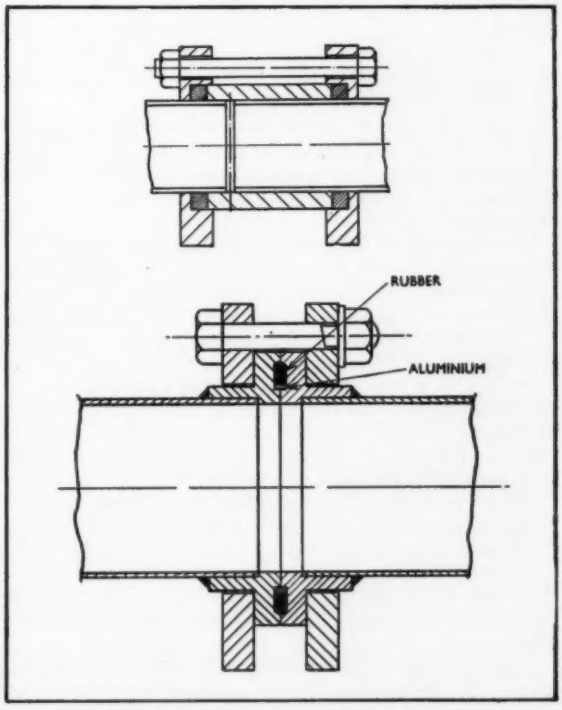

Fig. 5. Pipe coupling. An example of a coupling prone to faulty assembly (above). Redesigned coupling with metal-to-metal register (below).

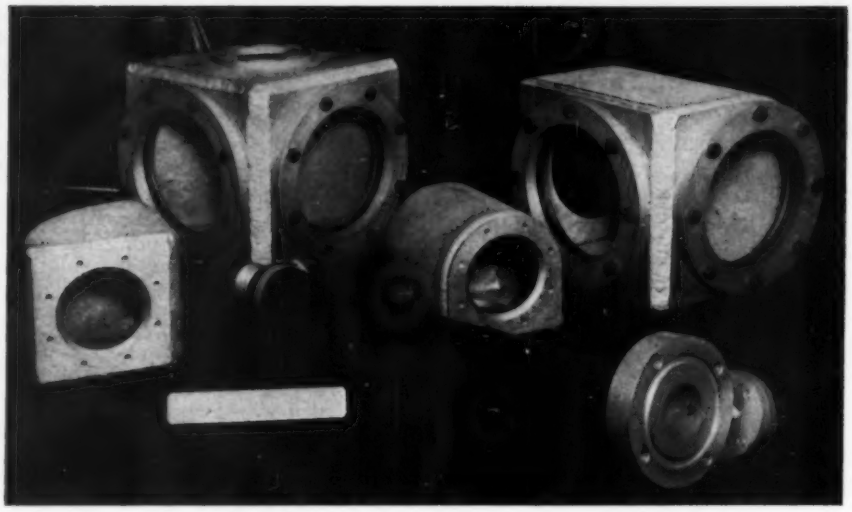

Fig. 6. High-vacuum pipe fittings. Coupling allows some misalignment and flexible connection isolates mechanical vibration. (Picture by courtesy of Metrovick Ltd.)

method lies in the absorbing system, which is susceptible to poisoning by other gases which may be present in the system.

The hydrogen-palladium gauge consists usually of an ionisation gauge separated from the vacuum system by a barrier of palladium which, when hot, is permeable only to hydrogen and is therefore used for the tracer gas. Best results are obtained by using the above method in conjunction with a standard leak. Sensitivity is of the order of 10^{-4} lusecs and the method has the advantage of speed. However, solvents like trichlorethylene and carbon-tetrachloride, which are used frequently for cleaning welds, upset the permeability of palladium. This drawback can be limited by inserting a liquid-air trap before the gauge.

In view of the high adsorptive capacity of this kind of trap for hydrogen as well as air and other gases, for greater sensitivity it is advisable to use solid CO_2 instead of liquid nitrogen. The method requires a standard leak and in a given case the actual leakage rate is calculated by means of the simple relation leak rate =

$$\text{standard leak} \times \frac{\text{response of instrument during test}}{\text{response of instrument for standard leak.}}$$

The type of response by means of this instrument is shown in Fig. 2. The smallest detectable leak is between 10^{-4} and 10^{-3} lusecs.

The presence of trichlorethylene and other halogenated solvents affects seriously the adsorptive capacity of the charcoal. Moreover, it may become saturated with water vapour with a resultant loss of sensitivity. Its advantages are cheapness, quickness of response and the fact that it can be used while out-gassing is in progress.

Another method about which further information will be awaited with interest employs a moderate pressure within the system to be tested and uses a modified Katharometer to measure the leakage. This system is rapid and has a reasonable sensitivity (10^{-2} lusecs).

All methods requiring a standard leak depend to a great degree upon the reliability of the leak device. Such methods as a flattened capillary were found to be unstable and a satisfactory substitute had to be found. The most reliable leak was produced by finely-divided aluminium powder compressed by means of a bolt between two sintered metal discs.

Another topic of considerable practical importance discussed by Kronberger was the construction of joints and flanges for high vacua. A number of do's and don'ts (Fig. 3) were given in the paper. It is recommended that, wherever possible, connections should be made by welded joints rather than by couplings or flanges. So far as the U.K.A.E.A. are concerned, argon-arc welding is used almost exclusively for fabrication purposes. Some joints, however, are made by vacuum brazing.

Objections were levelled at some of the recommended procedures; for example, those employing intermittent welds (see Fig. 3). These objections were made on the grounds that the procedures make leak location difficult, because this form of construction allows the probe gas to pass over the crevice between the welds.

When defective welds have been located, it is necessary to grind away the defective area and reweld. Attempts to superimpose another welding run over a defective bead usually result in converting a leak into a larger number of smaller leaks. Generally, when a weld fails to pass the acceptance test it is due to a fairly large hole arising from a relatively gross error in welding technique rather than from a large number of small holes.

Various types of joint were described, among them an interesting double O-ring joint (Fig. 4) suitable for large pipe-lines. This particular joint has the advantage of allowing testing to be carried out without the need to evacuate the entire system. All that needs to be done is to evacuate the space between rings and to note the pressure rise. Joints of this kind can effect a great saving in time, particularly when the system is a complex one.

For flange joints, O-rings make a very suitable gasket at ordinary temperatures and when properly compressed the faces of the flanges should be in contact. A joint which does not employ any form of metal-to-metal register is likely to prove troublesome. Difficulties which some users had encountered with PTFE packings arose from the tendency of this material to creep at temperatures near the upper end of its range. If the PTFE jointing is properly trapped, however, it will give good service.

For higher temperatures, flanged joints should be avoided and welding resorted to wherever possible. If flanged joints have to be employed, however, metallic jointing rings are used. With metallic gaskets the yield point of the gasket material must not be exceeded, a condition which can be observed by using gaskets with a mechanical register or by ensuring that the allowable bolt load is not exceeded. The extension of the bolts can be used as a measure of the compression of the joint.

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RUSSIAN ARTICLES ON CHEMICAL ENGINEERING (3)

A select list of articles on chemical engineering or allied subjects which have appeared in the Russian literature during the past two years is presented below. It is intended to publish further lists from time to time, depending upon the number of articles on these subjects appearing in the Russian literature.

General Description of Subject Matter	Title of Article (Free translation)	Authors	Journal
Nitrogen industry technology.	Questions of technological progress in the nitrogen industry.	L. A. Kostandov.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol 1, No. 6, p. 602.
Nitrogen industry technology.	K. A. Timiryazev and nitrogen problems.	N. A. Zhavoronkov.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 6, p. 606.
Nitrogen industry technology.	Some questions of theory and practice in ammonia synthesis.	S. S. Lachinov and V. A. Kurkovskii.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 6, p. 610.
Nitrogen industry technology.	Production of hydrogen and synthesis-gas by catalytic conversion of hydrocarbon gases.	A. G. Leibush.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 6, p. 638.
Nitrogen industry technology.	Various uses of hydrocarbon gases in the nitrogen industry.	—	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 6, p. 648.
Nitrogen industry technology.	Comparison of different schemes for the production of industrial naphthalene.	B. M. Pats.	Koks I Khimiya (Coal and Chemistry), 1957, No. 5, p. 39.
Nitrogen industry technology.	Technical progress in production of nitrogen fertilisers.	A. M. Dubovitskii and Ya. I. Kilman.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, No. 2, p. 139.
Alkali industry technology.	Development of the potassium industry.	V. M. Borisov and N. A. Afanacev.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, No. 2, p. 146.
Sulphur and sulphuric acid technology.	Methods of roasting sulphurous raw materials.	K. M. Malin.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, No. 2, p. 174.
Sulphur and sulphuric acid technology.	Conference on the preparation of sulphurous gas from pyrite and sulphur.	M. A. Koloskov.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, No. 2, p. 239.
Antibiotics, pharmaceuticals.	Progress in chemical antibiotics in recent years.	A. S. Khokhlov and M. M. Shemyakin.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 4, p. 377.
Antibiotics, pharmaceuticals.	Achievements in the field of vitamin production.	V. M. Berezovskii.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 4, p. 443.
Operating experiences.	The removal of scale forming in the evaporation of solutions of sodium sulphate.	N. A. Ushatinskii, et al.	Khimicheskaya Promyshlennost (Chemical Industry), 1956, No. 6, p. 324.
Operating experiences.	Results of studies of the performance of high-speed centrifuges.	A. P. Ponomarenko.	Sakharnaya Promyshlennost (Sugar Industry), 1956, No. 9, p. 55.
Operating experiences.	Improving the technology of salt crystallisation.	N. I. Tinkin.	Khimicheskaya Promyshlennost (Chemical Industry), 1956, No. 6, p. 368.
Drying.	Method of calculation of the movement of free-flowing materials in revolving and, in particular, soda kilns.	N. M. Boguslavskii.	Khimicheskaya Promyshlennost (Chemical Industry), 1956, No. 2, p. 89.
Drying.	Calculation of drying time for damp materials under static conditions by convection.	N. S. Mikheeva.	Teploenergetika (Heat Energy), 1957, No. 2, p. 24.
Size reduction.	Determination of output of shaft mills (hammer mills with shaft classifiers).	V. P. Romadin, M. L. Kisel'nof and N. V. Sokolov.	Teploenergetika (Heat Energy), 1956, No. 3, p. 58.
Size reduction.	Vibrational comminution of materials.	M. L. Morgulis.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, No. 2, p. 186.
Size reduction.	Determination of the grindability of a fuel mixture.	K. Ya. Polferov.	Teploenergetika (Heat Energy), 1956, No. 12, p. 26.

LATEST DEVELOPMENTS IN

FLAME FAILURE PROTECTION — PART 2*

The types of thermoelectric devices available are dealt with, as are their installation requirements, applications as controllers and the maintenance points to be observed

Thermoelectric Devices

3.1 INSTALLATION—GENERAL

The gas industry cannot approve the use of any type of device with an inherent ability to fail to danger. It must also be realised that any device, however satisfactory, can be rendered ineffective, and therefore dangerous, by incorrect installation. Included in this section are descriptions of some types of device which, although they do not fully satisfy the Indispensable Characteristics of Section 1.3, may be encountered.

The requirements listed in Section 2.1, (a) to (e), must also be observed in fitting this type of flame failure device. Other requirements are:

(a) the thermocouple must be correctly located with respect to the pilot flame, according to the makers' instructions;

(b) the thermocouple should be shielded from radiation from sources other than the pilot flame.

(c) care must be taken to avoid damage to the thermocouple leads, especially at the point where they are connected to the body of the valve. On assembly or reassembly, attention should be given to the cleanliness of the electrical connections;

(d) the pilot and thermocouple must be located where they are not subject to excessive draught;

(e) the pilot flame must not be in danger of being smothered by products of combustion;

(f) the pilot burner assembly should be rigidly attached to a metal support of substantial cross-section which is, if possible, an extension of a colder portion of the appliance. This will enable heat to be conducted away from the thermocouple.

(g) the pipe carrying gas to the pilot burner should be made as rigid as possible, since vibration of this connection has been known to extinguish the pilot;

* Sections 1, 2 and 4 of this review of Flame-failure Devices were published in the December, 1957, issue of *British Chemical Engineering*, p. 654.

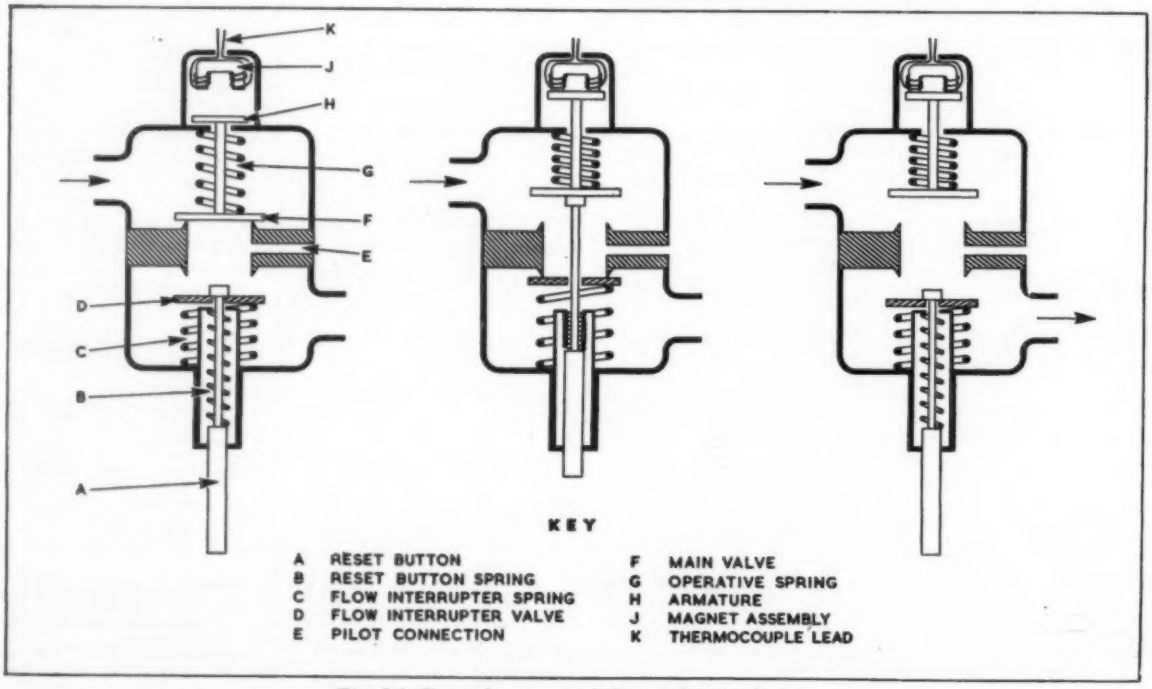

Fig. 3.1 Gas valve types of thermoelectric device.

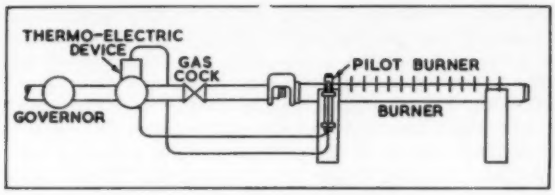

Fig. 3.2. Direct protection.

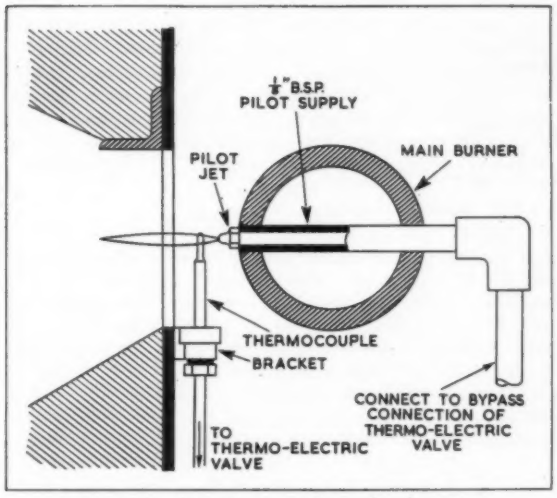

Fig. 3.3. Arrangement of a pilot burner

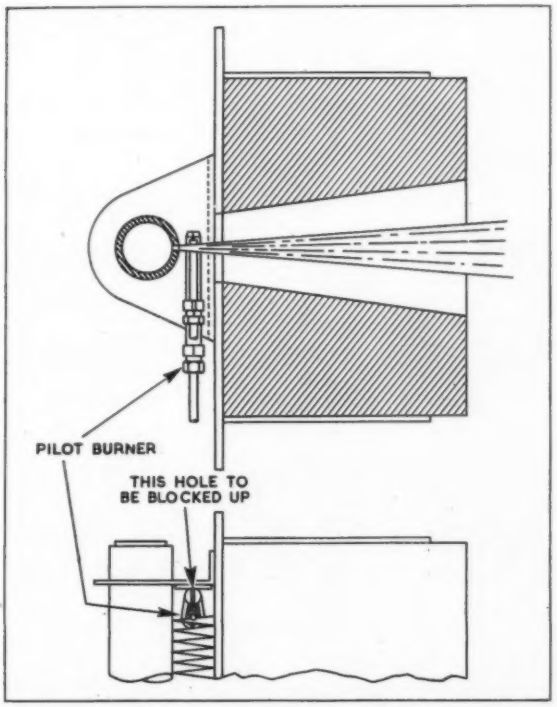

Fig. 3.4. A further arrangement of pilot burner. Both burners (Figs. 3.3 and 3.4) have the advantage that a drop in pressure at the pilot burner when gas passes to the main burner does not interfere with normal operation.

(h) the gas valve should be mounted sufficiently rigidly to prevent its being affected by undue shock or vibration;

(i) the device must, wherever possible, be so mounted that gravity assists the closing of the gas valves. Only in cases where, for local reasons, this is impossible, may devices be fitted with the electro-magnet at the bottom. Only those devices in which the main valve is adequately aligned by at least two guides may be fitted so that the movement of the valve spindles is other than vertical;

(j) the portion of the device which carries the press button used in lighting up must be fixed where the operator can, without difficulty, hold the button in and at the same time observe and light the burner; and

(k) on all but the smallest installations, a burner cock, or cocks, should be fitted and kept closed until all other lighting-up procedure has been performed.

Where mains-energised units are used, installations should comply with the Electricity (Factories Act) Special Regulations, 1908 and 1944, and the "Regulations for the Electrical Equipment of Buildings", published by the Institution of Electrical Engineers.

Additional factors extend the installation requirements in the case of thermoelectric devices, for the operation of such devices depends upon the provision of the correct temperature conditions at the thermocouple head. Since a thermocouple depends for its operation on a temperature difference between the hot and cold junctions, it is necessary to ensure not only that the hot junction is at a sufficiently high temperature, but also that the cold junction is not overheated. This is not always easy, as the two junctions are usually within one or two inches of each other; difficulty arises particularly when the thermocouple is mounted inside a lined combustion space. For this reason, and also in order to ensure sufficiently rapid cooling in the event of flame failure, this type of device should not be employed in locations where the thermocouple and pilot burner assembly (excluding of course, the hot junction of the thermocouple) will reach a temperature exceeding 250-300°C. For special circumstances where the standard thermocouple cannot be satisfactorily located, longer couples can be obtained.

The use of an uncontrolled pilot in any installation is not approved by the Committee, since it contravenes Indispensable Characteristic (c), Section 1.3. The use of a lighting torch to heat the thermocouple tip of an installation involving a thermoelectric device is not recommended, since there is a possibility that such a torch could be arranged to act as an uncontrolled pilot. Design of both appliance and lighting torch should be such as to prevent this as far as possible in any case.

3.2 CONTROL OF SINGLE-BURNER INSTALLATIONS

3.2.1 DIRECT CONTROL

3.2.1.1 *Gas Valve Type*

A typical thermoelectric device of the gas-valve type is shown in Fig. 3.1. When the push button A at the base of the body is pressed upwards, the flow interrupter valve D is moved on to its seating, thus sealing the exit port to the main burner. Further movement of the push button A raises the main valve F, which action admits gas to the pilot burner through the connection E in the body of the device. The pilot burner may then be lighted. Upon completion of the movement of the push button, the armature H will be pressed against the electromagnet J and, after about 30 seconds, the temperature of the thermocouple is such that sufficient current is generated to energise the electromagnet J, which will thus hold the armature H in position and so retain the main gas valve F open. At this

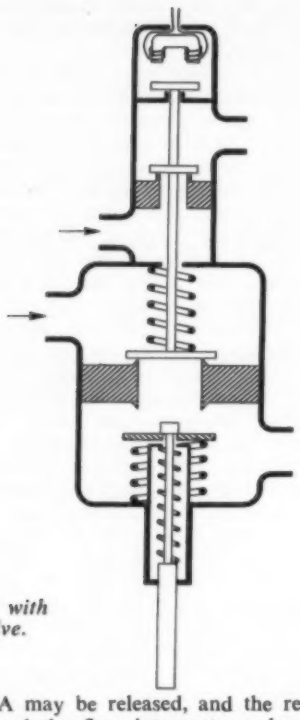

Fig. 3.5. *Gas valve with separately-fed pilot valve.*

stage, the push button A may be released, and the reset spring B will force it and the flow interrupter valve D downwards, thus opening the main gasway and so allowing gas to pass to the main burner. If the gas supply fails, the pilot flame goes out, the thermocouple cools, and the current falls. The electromagnet J can thus no longer hold the armature H in position, so the main gas valve F is returned to its seating. No gas will flow again until the whole setting operation is repeated.

Fig. 3.2 shows a suitable arrangement for direct control of the gas supply using a thermoelectric device of the gas-valve type. Figs. 3.3 and 3.4 show two further ways in which a pilot burner may be arranged. They both have the advantage that a drop in pressure at the pilot burner when gas passes to the main burner does not interfere with normal operation.

3.2.1.2 *Gas Valve with Separately Fed Pilot Valve*

A further type of device similar in principle is shown in Fig. 3.5 but, while in the type of device described in Section 3.2.1.1 above, the pilot connection is taken through the main valve body, here the gas supply to the pilot burner passes, via separate connections, through a valve mounted on the same spindle as the main valve and armature, but separately housed. The manner of operation of this type of device is similar to that of other thermoelectric devices and will be clear from Fig. 3.5. This type of valve can, of course, be used in a system of direct control, but since it then shows no advantages over the type considered in Section 3.2.1.1 and is more expensive than that type, it is rarely used except in indirect systems of control (see Section 3.2.2.1) or in control of multi-burner installations (see Section 3.3.3).

3.2.1.3 *Gas Valve without Pilot Connection*

Fig. 3.6 shows the arrangement for direct control of the gas supply using this type of device. When the device is to be used, the lighting torch is used to heat the thermocouple; care must be taken that the flame is not too large, otherwise the cold junction may be heated as well as the hot junction so that insufficient current will pass through the electromagnet to allow the thermoelectric valve to be held open. When the e.m.f. generated by this operation is sufficient to energise the electromagnet, the button on the top plate of the device is depressed, thus compressing the press button spring and the spring between the magnet and valve. The magnet is then in contact with the armature on the diaphragm and, when the button is released, the magnet returns to its normal position, carrying with it the armature and diaphragm, thus opening the gas valve and allowing gas to pass to both pilot and main burners. *The lighting torch must then be removed.*

On flame failure, the electromagnet ceases to be energised and the valve closes under the action of both spring and gravity. The use of a lighting torch to heat the thermocouple makes this method one which *cannot be recommended*, since there is a temptation to use the lighting torch as an uncontrolled pilot. The use of an uncontrolled pilot with a gas supply taken from upstream of the valve is an alternative, but this would, of course, directly contravene Indispensable Characteristic (c), Section 1.3.

3.2.2 INDIRECT CONTROL

3.2.2.1 *Gas Valve Type*

A number of systems has been evolved in which thermoelectric gas valves are used indirectly. Not all of these are fully satisfactory; in this section two satisfactory methods are shown, followed by an example which, for given reasons, is not recommended. It will be noted that in most cases the indirect control is exercised through a relay valve which should be of the "on-off" type, since the "high-low" type is liable to pass gas when in the closed position.

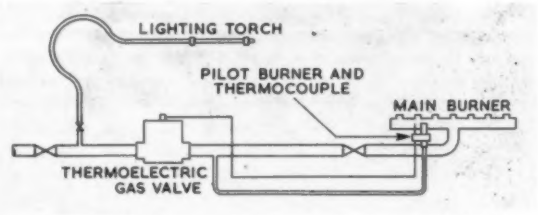

Fig. 3.6. *Direct protection;* not *recommended.*

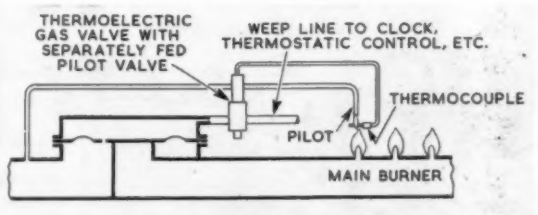

Fig. 3.7. *Indirect control: Method* 1.

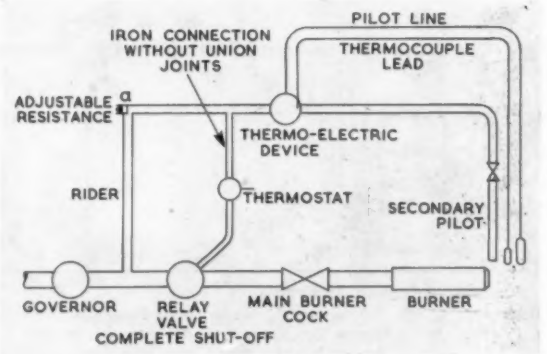

Fig. 3.8. *Indirect control: Method* 2.

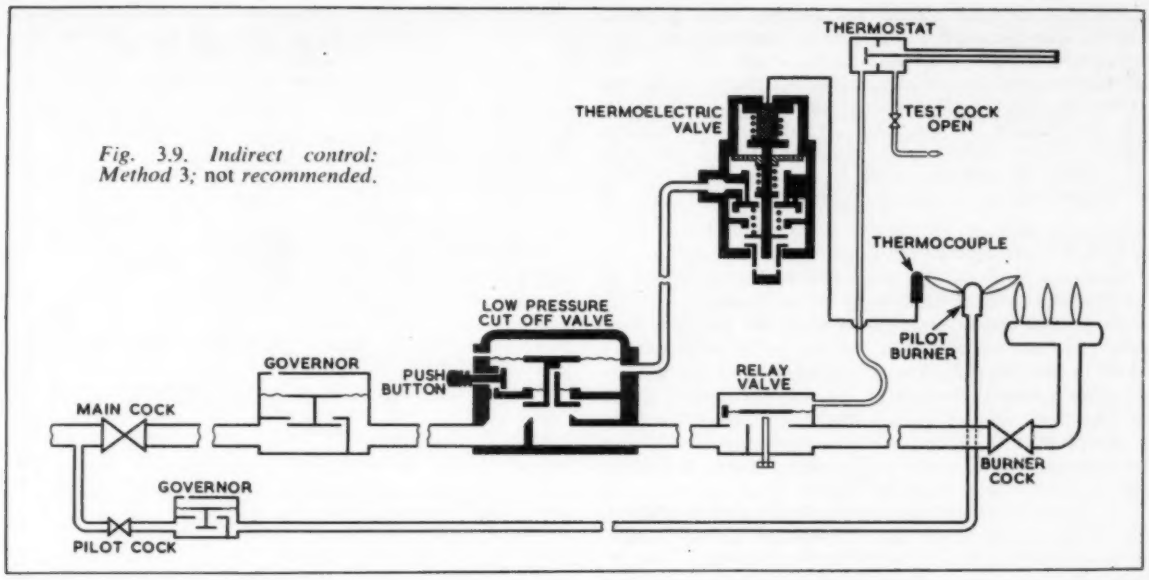

Fig. 3.9. Indirect control: Method 3; not recommended.

Method 1—Satisfactory

This method is illustrated in Fig. 3.7. The gas valve used is of the type with a separately fed pilot valve, as described in Section 3.2.1.2. The pilot connection is taken from upstream of the relay valve, while the main gas valve of the thermoelectric device is placed in a line leading from the upper chamber of the relay valve. In the event of flame failure, the valves in the thermoelectric device will close, thus isolating the pilot burner and also allowing pressure to build up over the relay valve diaphragm, which in turn closes the main gas way. When relighting, the press button at the base is pushed upwards. The flow interrupter is then in place, so that the relay valve remains closed, but the pilot valve is held open, and the pilot burner can be lighted. When the pilot flame is properly established, the push button may be released to open the main gas valve in the body of the thermoelectric device. The pressure on the top of the relay valve is thereby released, so that gas may pass through the relay valve to the main burners.

The line from the main body of the thermoelectric device can be connected to a thermostat or clock control or both. Should either of these controls operate to close the relay valve, the pilot burner will be unaffected. This method of control cannot be applied using the simpler type of thermoelectric gas valve described in Section 3.2.1.1 which has only one inlet gas connection, while the suggested method demands independent connections to the pilot burner and to the top of the relay valve. It would be possible to supply the pilot burner through the weep of the relay valve, but in this case when the push button at the base of the device was pushed upwards, the main gas way would be opened immediately, thus leading directly to a dangerous situation. Furthermore, if a simpler device than that recommended were to be used, automatic temperature control would require the use of two relay valves.

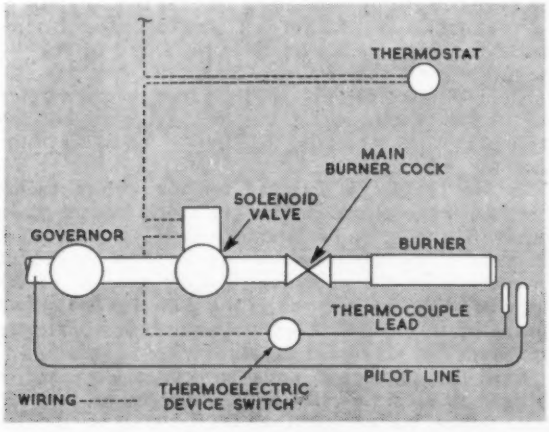

Fig. 3.10. Single-switch type of device; not recommended.

Method 2—Satisfactory

This is illustrated in Fig. 3.8. With this system the same relay valve serves the flame-failure device and the thermostat and it is important that the relay valve should be of the complete shut-off type. A rider by-passes the relay valve and handles 10% of the total gas rate required; the remainder is handled by the relay valve. A metering orifice is located at (a) and is designed to pass the required quantity of gas with a pressure drop of approx. 1 in. w.g.

A thermoelectric valve, as described in Section 3.2.1.1, of appropriate size is fitted in the rider, and the weep line from the relay valve, after passing through the thermostat, is fed into the rider between the restrictor and the thermoelectric valve. It will be clear that operation of the thermostat will reduce the gas rate to that carried by orifice (a) i.e., to a little over 10% of the maximum gas rate. Closure of the thermoelectric valve due to pilot failure will cause the relay valve to close rapidly, as a feed back is obtained through the rider. For this reason a clogged weep orifice will not interfere with the operation of the system and the orifice at (a) is always so large that it is extremely unlikely that it will become clogged with foreign matter.

A restrictor may be fitted between the relay valve and the thermostat in order to reduce the rate of opening of the relay valve. This is a desirable feature when large gas rates are being handled. This restricting jet is always larger in diameter than the weep orifice. Clock control may be inserted in the weep line, in which case the gas rate will fall to that passed by the rider when the clock

valve is shut, or clock control may be inserted in the rider, in which case the main burner will be completely shut off, leaving only the thermocouple burner alight.

If proportional (modulating) control is required, the gas passing through the rider system may be returned to the main gas stream. In this case an additional restricting orifice must be inserted in the main gas stream after the relay valve; the pressure drop across this orifice should be the same as that across the restrictor (a).

Method 3—Unsatisfactory

There is a type of thermoelectric device, as shown in Fig. 3.9, which differs from those so far considered in this review in that the valve is closed when the electromagnet is energised and the armature attached to the valve spindle is held in position. This type of device is used in conjunction with a special weep-reset low-pressure cut-off valve, also shown in Fig. 3.9. This mode of operation entails the escape of a small volume of gas each time the lighting procedure is carried out and for this reason small vent holes are provided in the valve bonnet.

The fitting of the device shown in Fig. 3.9 is possible only with the use of an uncontrolled pilot, thus contravening Indispensable Characteristic (c), Section 1.3, or by using a lighting torch to heat the thermocouple, a practice which is not recommended, since there is the possibility that the lighting torch will, in these circumstances, become an uncontrolled pilot. For these reasons *this system cannot be recommended* for use in industrial installations. This recommendation is made without prejudice to its use with central-heating installations, for which it was devised.

It is a disadvantage in that, if automatic temperature control is required, an additional relay valve must be employed.

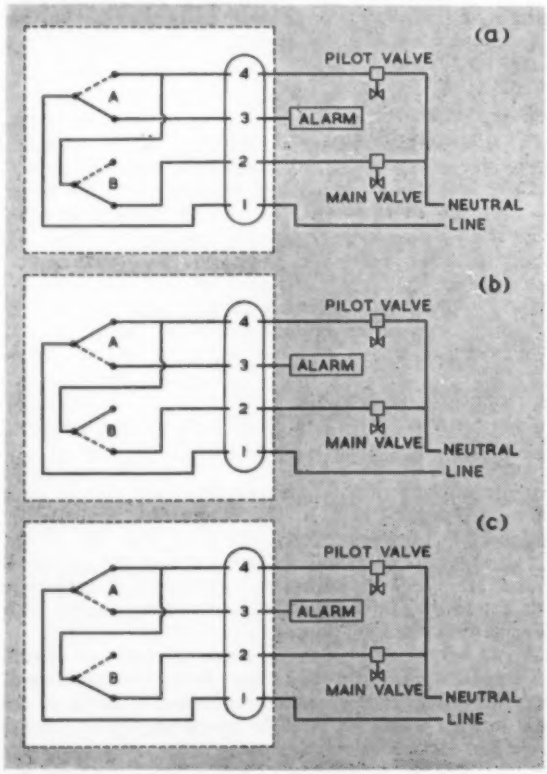

Fig. 3.11. Double-switch type of device.

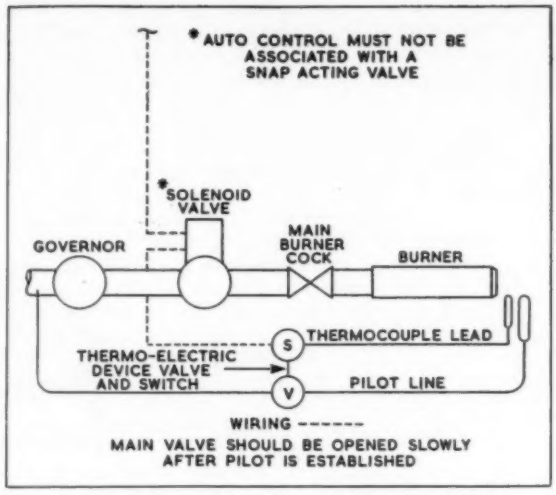

Fig. 3.12. Combined gas valve and switch.

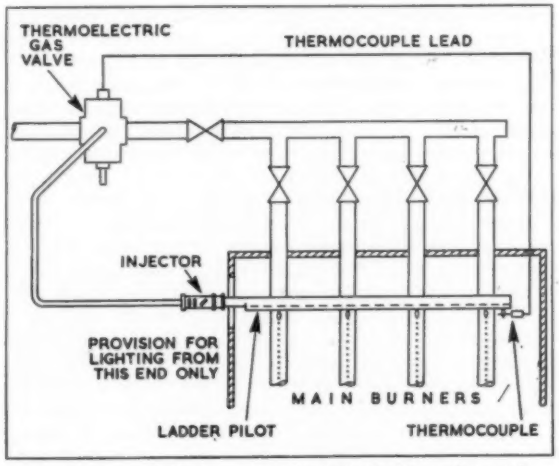

Fig. 3.13. Installation of multi-hole ladder pilot with direct operation of gas valve.

3.2.2.2 *Single Switch Type*

Thermoelectric-switch type devices are similar to the gas valve devices in that they are operated by the heating of the thermocouple by means of a pilot flame. They are so designed that a switch does not close until the thermocouple is sufficiently hot for the armature to be held by the magnet, and until the press button has been released. Similar thermocouple and pilot burner assemblies are used for the device as for the gas valve type, and the previous remarks concerning the location and fitting of the pilot will apply.

The switch type is intended for use with a mains-energised valve placed in the gas supply to the main burner. The pilot burner assembly is fed from a point upstream of the solenoid valve and a control cock must be provided in the pilot line. The arrangement of the single-switch device is shown in Fig. 3.10 and *this system cannot be recommended* because uncontrolled pilots are employed.

When thermostatic or similar controls are involved, a solenoid valve is necessary to give rapid shut down on flame failure, but the automatic control must act through a relay valve to give the necessary slow opening. Solenoid-operated relay valves are now available which combine

rapid shut down with adjustable re-opening time. These will be dealt with in a later publication.

3.2.2.3 *Double Switch Type*

The principle of this type of device is shown diagrammatically in Fig. 3.11. In the shut-down state, as at (a) in Fig. 3.11, no current can reach either pilot or main solenoid valves, and unless the whole device is isolated an alarm bell is in circuit.

The lighting procedure is as follows: the mains are switched into the circuit (when the alarm, if fitted, will sound) and then the lever on the device is moved up, thus altering the position of both the switches. The lever is attached directly to the switch controlling the main gas valve, but merely pushes the switch operating the pilot valve into place. This position is shown at (b) in Fig. 3.11, where it is seen that current passes to the solenoid of the pilot-gas valve, so that the pilot can then be lit. When the pilot is established, it heats a thermocouple which actuates an electromagnet which, in turn, will hold the switch controlling the pilot valve open.

If the pilot is not established when the lever is released, the position of the switches will revert to that shown at (a), and no gas will pass to the apparatus. If the pilot is properly established when the lever is released, then not only will contact be maintained between the mains and the solenoid of the pilot valve, but also contact will be made between the mains and the solenoid of the main gas valve which will then open, a situation shown at (c) of Fig. 3.11.

Should flame failure occur, the electromagnet will no longer be energised by current derived from the thermocouple, and the system will revert to the position shown at (a) in Fig. 3.11, that is, all gas passing to the appliance will be cut off and the alarm, if fitted, will be brought into circuit. With the degree of protection afforded by such a device *this system can be regarded as satisfactory.*

3.2.2.4 *Combined Gas Valve and Switch*

A thermoelectric device is available which incorporates both a valve to protect the pilot flame and a switch to control a mains-energised solenoid valve in the supply to the main burner. The device is shown in a typical layout in Fig. 3,12. Since this system, as opposed to the single switch system described in Section 3.2.2.2, protects the pilot as well as the main burner, *it is satisfactory.*

3.3 CONTROL OF MULTIPLE BURNERS

Before proceeding to describe the methods available for the protection of multi-burner systems, it must be emphasised that nothing in this section in any way prejudices the view expressed in Section 1.7 that multiple burners should be eliminated wherever practicable.

The simplest and most satisfactory method of controlling multiple burners is, of course, to arrange their layout so that all can be lit directly by one central pilot. It should be noted that all the systems described below may be fitted with thermostatic control.

3.3.1 LADDER BRIDGING PILOT BURNERS

The attitude of the gas industry towards ladder pilots has been made clear in Section 1.7; briefly, they may be regarded as acceptable, but not desirable. Nevertheless, considerations of economy or of space may dictate the use of ladder bridging pilot burners. The types available are described in Section 1.7.1 (see December issue).

Ladder pilot installations are satisfactory only if the point of ignition is at the end of the ladder remote from the thermocouple. In making an installation, every effort should be made to render ignition at other points impossible. The devices described in Sections 3.2.2.3 and 3.2.2.4 can also be used in conjunction with a ladder bridging pilot burner.

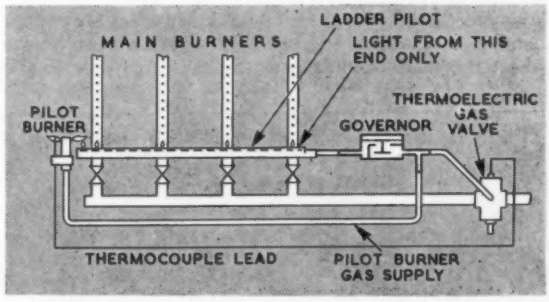

Fig. 3.15. Installation of slot-type ladder pilot.

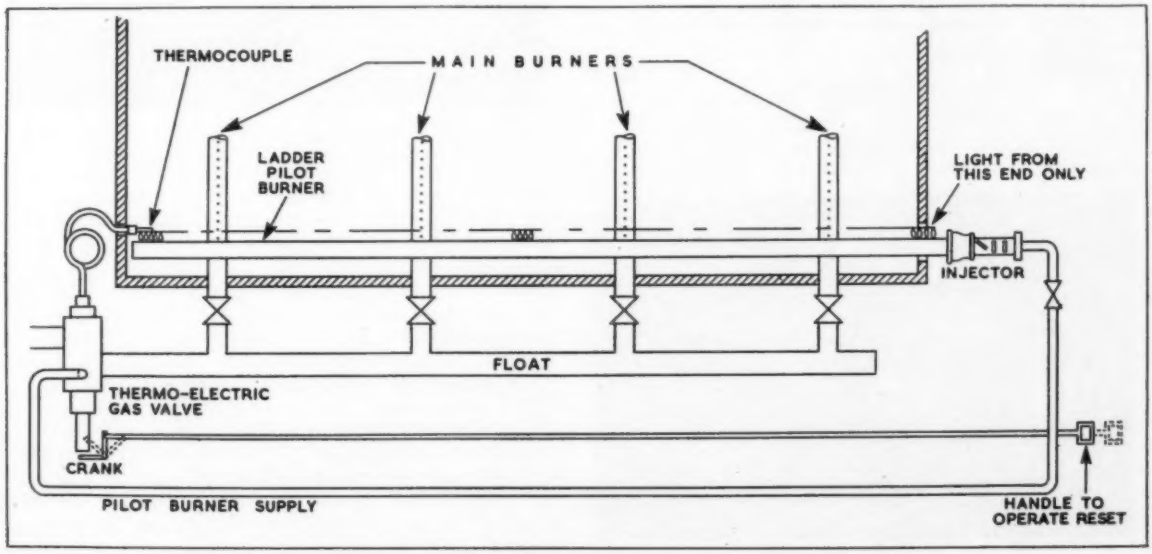

Fig. 3.14. Installation of multi-hole ladder pilot with indirect operation of gas valve.

3.3.1.1 *Aerated Multi-hole Ladder Pilots*

The method of installation of multi-hole ladder pilots is shown in Fig. 3.13. One end of the ladder pilot is adjacent to the thermoelectric valve, so that the operator must light the pilot burner at that end if he is also to operate the thermoelectric valve. The thermocouple energising the thermoelectric valve is located at the opposite end of the ladder pilot. Thus, until flame is established along the entire length of the ladder pilot, the thermocouple will not be heated and so the main gas valve will not open. It may be necessary to enlarge the orifice controlling the flow of gas to the ladder pilot from the thermoelectric gas valve.

A disadvantage from which this system suffers is the length of thermocouple lead required, although lengths of up to 15 ft are now available. However, an alternative method of installation, shown in Fig. 3.14, deals with the situation by using remote control of the thermoelectric valve. Operation of a cable system can press the push button at the base of the thermoelectric valve into position so that both valve and thermocouple head can be located at the end of the ladder pilot opposite to that at which the pilot will be lit. Apart from the remote-control arrangements, this mode of installation is exactly similar in principle to that described above.

3.3.1.2 *Post-aerated Slot Ladder Pilot Burner*

The method of installation of post-aerated slot ladder pilot burners is shown in Fig. 3.15. In order to provide a low heat release, the inlet pressure to the slot burner is governed to a low value, and this means that the flame produced is not capable of heating a thermocouple sufficiently to hold a thermoelectric valve open. For this reason it is necessary to provide a separate pilot burner to heat the thermocouple, and the gas supply for this is shown coming from a tee placed in the supply to the slot burner. It is essential that this intermediate pilot burner be so located that it fires not only on to the thermocouple head, but also on to the end of the slot burner. Such pilot burners can be obtained fitted with a clip for mounting on to the slot burner in a manner that ensures correct positioning.

With the exception of the use of the intermediate pilot, the system shown in Fig. 3.15 is exactly similar to that shown in Fig. 3.13 in the previous Section 3.3.1.1. When the pilot burner is lit, flame runs along to the end where it ignites the intermediate pilot burner which, in turn, heats the thermocouple, and the main valve is then held open.

The use of an intermediate stage in heating the thermocouple is theoretically a disadvantage, but in practice the blockage of the supply to the ladder pilot without affecting the intermediate pilot would be unlikely. The use of separate tappings on the body of the device to feed the ladder pilot and the intermediate pilot is less desirable than the arrangement shown in Fig. 3.15, since the supply to the ladder pilot may become blocked while the intermediate pilot continues to heat the thermocouple head. This can give rise to a condition of danger. With one tapping, however, blockage would cause not only failure of the ladder pilot, but also the extinction of the intermediate pilot, with consequent shutting down of the main burners.

3.3.2 THERMAL SWITCH TYPE

One way in which it is possible to control multiple burners is by means of thermal switches. These consist of a rod-type thermal expansion unit which, when heated by a pilot flame, closes a switch, as seen in Fig. 3.16. One

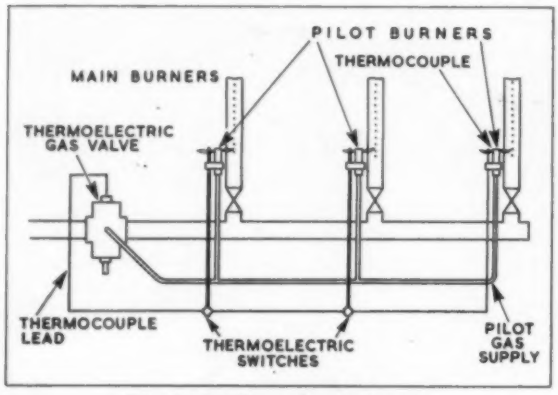

Fig. 3.16. Thermal switch type.

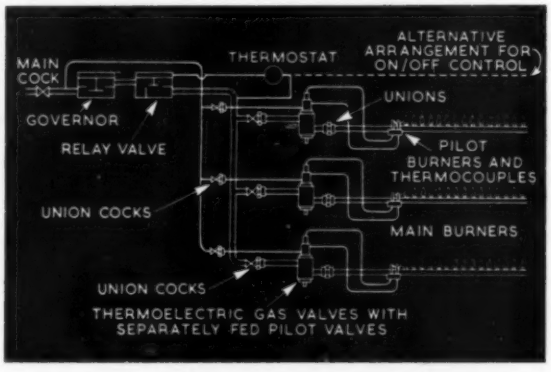

Fig. 3.18. Gas valve with separately-fed pilot valve—independent control of multi-burners.

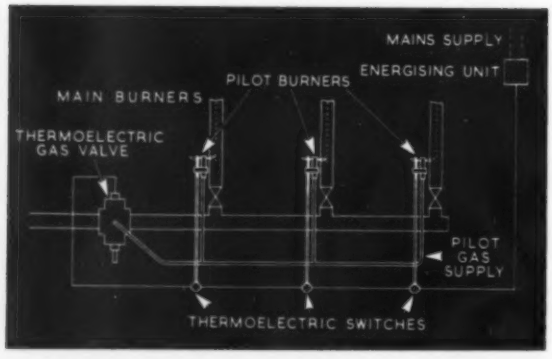

Fig. 3.17. Thermal switch type—modified.

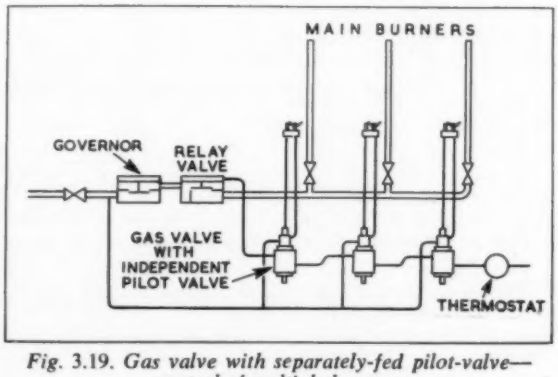

Fig. 3.19. Gas valve with separately-fed pilot-valve—control of multiple burners.

such unit is attached to all save one of the burners of a multi-burner system—the remaining burner is protected by the usual form of thermocouple head heated by the pilot flame. The thermal switches are in series with the thermocouple and the electromagnet, so that all pilots must be established before the thermoelectric valve will be held in the open position; failure in any one pilot will cause the valve to close.

In using thermal switches, it must be remembered that there will be a potential drop across each switch and along the leads connecting it to neighbouring switches. Since the current supplied by a thermocouple to a circuit is limited by the resistance of that circuit (including that of the thermocouple itself), it is not advisable to attempt to protect more than four burners with these devices.

A development from the original idea replaces the thermocouple by a mains energisation unit, comprising a step-down transformer and rectifier. As can be seen from Fig. 3.17, each burner is fitted with, and protected by, a thermal switch. As before, the main-gas way can be opened only when each switch unit is heated by its pilot jet to complete the circuit which will hold the main-gas valve open. Also, should any one pilot fail, the circuit will be broken, and the main-gas valve will close, as before.

3.3.3 GAS VALVE WITH SEPARATELY FED PILOT VALVE

A more flexible method of control of multiple burners is afforded by thermoelectric flame-failure devices incorporating an independent pilot valve. This type of device has been illustrated and its mode of operation is explained in Section 3.2.1.2 of this Review. It can be installed in a variety of ways according to the requirements.

Since the pilot valve is in a separate section of the device and does not communicate with the main-gas way, the gas supply to it may be taken from the inlet to the governor; thus, when the relay valve closes under thermostatic control, the pilot supply is unaffected.

Fig. 3.18 shows the method of installation for independent control of each burner. It will be noted that each device is placed between a union cock and a union in order that it may be removed without disturbing the rest of the installation. An independent supply is taken from a point upstream of the relay valve to the pilot valve portion of each device. The normal lighting procedure is carried out on each burner in any order. Should any pilot be extinguished, the valve will close, shutting off gas to both the pilot and main burners which it is controlling. The remaining burners will continue to operate under thermostatic control.

Fig. 3.19 shows another method of installation which will shut off all main burners in the event of flame failure at any one pilot. Each burner is fitted with a separate device; the main valves are connected in series in the weep line of a relay valve, which must be of the complete shut-off type, and the pilot valves are connected separately to a point upstream of the relay valve. The normal lighting procedure is carried out, and when the last thermoelectric device is in operation and the push button released, the relay valve will open and allow gas to pass to the main burners, where it will be ignited by the pilot flames. If any one pilot is extinguished, the valves in the device associated with it will close, thus closing the weep from the relay valve. This shuts off the main gas, but retains the unextinguished pilots.

3.4 SERVICING

Attention must be given to the following points when servicing these devices:

(a) examination of the thermocouple, and, if necessary, its replacement. Attention should also be paid to the electrical connection between the thermocouple head and the body of the device;

(b) the pilot burner is normally provided with two or more ports connected by a slot. This slot must be kept clean and the pilot burner should not be fitted in any position in which the slot is likely to become clogged with foreign matter;

(c) dressing of any leather diaphragms which may be employed;

(d) cleaning of weep orifices, jets and air ports;

(e) examination of the installation to ensure that it is rigidly mounted and that the pilot is properly located with respect both to the main burner and to the thermocouple; and

(f) a shut-down test to ensure that the device is left functioning correctly.

Isotope Separation in Supersonic Jets

Summary of lecture of Professor Dr.rer.nat. E. W. Becker, Marburg/Lahn, held on the occasion of the handing over of the Dechema Prize 1956 of the Max-Buchner-Forschungsstiftung at the 29th Dechema Colloquium on November 22, 1957, in Frankfurt (Main)

THOSE SPECIES of a chemical element with different neutron content in the nucleus we refer to as isotopes. Since isotopes are strongly differentiated from each other in their nuclear physical properties, isotope separation plays an important role in obtaining nuclear energy. Of special importance is the enrichment of the heavy hydrogen isotope (preparation of heavy water) and the enrichment of the light uranium isotope U^{235}. Measured in energy consumption and in the amount invested, isotope separation plants today represent the largest industrial units set up for the production of a special material.

For the enrichment of U^{235} the "diffusion process" which goes back to G. Hertz is used in America, Great Britain and the Soviet Union. It rests on the difference of the diffusion rate of $U^{235}F_6$ and $U^{238}F_6$ in fine-pored membranes. The diffusion process has been developed to greater perfection in the last ten years. Although the American diffusion plants use an amount of electric current equal to about two-thirds of that produced in the West German Federal Republic, the method cannot be considered uneconomic in relation to the extraordinarily high production of these plants. Nevertheless, there are certain technical difficulties in using the fine-pored membranes which have only a limited life in the strongly corrosive and easily decomposed uranium hexafluoride.

In the lecture, a new separation process suitable for the uranium isotope is described which depends on the partial spatial demixing of the different heavy gases in a freely expanding supersonic stream. Because of difficulties in measurement, the process has so far developed chiefly using the lighter elements, but it can be experimentally shown that the results obtained with the lighter elements can be applied to the uranium isotopes. The specific energy consumption for the "jet separation process" is estimated to be roughly the same as that of the diffusion process. However, by avoiding the fine-pored membranes, there is a possibility that a series of technical advantages may be achieved. As a disadvatage there is a comparatively low absolute pressure which implies relatively high costs for the blowers required for re-compression of the uranium hexafluoride. It can nevertheless be assumed that these costs will be reduced in the course of further developments. It is intended to set up a research plant working with uranium hexafluoride for studying problems arising in the translation of the process on to a technical scale.

AMERICAN LETTER

American Petrochemicals Industry

DESPITE ever-rising living costs, the average American gives little thought to gasolene economy—being quickest on the gas at a traffic light in a 200-h.p. car is said by some pyschologists to be a substitute pattern for being quickest on the draw in a wild-west movie. This desire has resulted in a contest for more instant power in a fuel, rather than the European emphasis on maximum miles per gallon. In time, this has created a big demand for premium gasolenes heavily leaded and with octane numbers approaching 100. This trend is expected to continue and give rise to compression ratios of 12 or even more, and super-premium fuels with octane rating of 105 may become commonplace within the next decade.

It is fortunate that these high-octane fuels are so popular with the owners of new automobiles, otherwise an eventual large-scale adoption of gas turbines and jet engines for aircraft propulsion might seriously affect established refinery practices and economies. Even at the present time, it is said that only 200,000 bl of aviation gasolene are produced daily, although U.S. refinery capacity is 250,000 bl a day. However, any future reduction in aviation demand is expected to be offset several times by the increasing requirements of future motorists.

At present, about 43% of crude is used to produce high octane gasolene, and in the attempt to raise this figure numerous processes are used, such as reforming, alkylation and catalytic polymerisation. For instance, a premium-blend fuel might be compounded as follows:

	Volume %
Light alkylates (pentanes, etc.)	25
Iso-pentanes	11
Light cat. cracker fractions	22
Heavy reformates	34
Butanes	8
	100

A great many isomers exist in each group, and in a wide range of chain and ring-type compounds. The infra-red spectrometer makes possible the analysis of such complex mixtures, and in many cases can be adapted to give refinery control based upon the products and ratios desired.

The importance of alkylation, isomerisation and platinum reforming can be judged from the above formula, and it is anticipated that these processes will supply the super gasolenes of the next decade; further improvements should lower processing costs and also give still greater yields of the more powerful gasolene fractions.

As regards refinery capacity, a prominent U.S. oilman recently estimated that expansion in next decade might be:

Millions of Barrels of Crude a Day

	1957	*1967*	*Increase*
U.S.A.	8.5	12.0	3.5 (41%)
Foreign (free world)	7.0	14.0	7.0 (100%)
Total	15.5	26.0	10.5 (68%)

This anticipated increase may well require an investment of 10 billion dollars in new plant, quite apart from the upkeep and modernisation of existing installations. Thus, both to refinery companies and to the designers and manufacturers of petroleum plant, the future is bright.

It is believed that abroad a much greater emphasis will be placed on upgrading crudes and producing middle distillates than will occur in America, although these problems too are of increasing importance in America.

Quality requirements for middle distillates, fuel and lubricating oils are, of course, radically different from those of gasolenes. For instance, smoke reduction is important and a cetane factor might be envisaged as a means of developing a new quality and price scale. Some degree of isomerisation may also become necessary in order to balance demand with available distillates in some areas.

One of the most serious challenges facing the petroleum industry in the U.S.A. and abroad is the upgrading of crude and the removal of impurities such as sulphur, as well as compounds of iron, nickel, arsenic, vanadium and other metals. Sulphur can be removed at the refinery, although large amounts of hydrogen are often required, amounting from 50 to 200 cu. ft a barrel of distillate. Metallic impurities are usually particularly difficult to remove and give rise to catalyst poisoning, lowered quality and increased refinery operating costs. Economic large-scale processes for removing such impurities from crudes offer great scope for development in the next decade.

Petrochemicals

Only about 2% of America's petroleum refinery output is used for petrochemical production, yet this now represents some 25% of the total output of the entire chemical industry. In dollar value, this amounts to more than half of the total chemical output, which is estimated to be about $8.5 billion for 1957. While these present-day figures are impressive, the anticipated future expansion programme is equally significant, for the next decade should see the petrochemical section of the chemical industry rise to about 50% of the whole and approach an output value well over 60% of all U.S. chemicals. It is believed that the general expansion rate for petrochemicals is of the order of 15%—a rate seldom approached by other peace-time industries. This is encouraging to chemical plant manufacturers, since the present yearly expenditure of about 1 billion dollars on equipment for this industry is expected to be doubled, at least, by 1967.

With regard to products, a brief reference to some major primary products is of interest. The demand for ethylene continues to rise and the current production level of 4 billion lb a year may be increased to 7 billion by 1967. It is expected that polyethylene and ethylene oxide production will together account for half of this figure.

Should the latest low-pressure processes for polypropylene come into widespread use, a phenomenal growth may well occur in its production. Another chemical with a further growth potential is butadiene.

While synthetic ammonia is not exclusively a petrochemical product, it is noted that despite a large overcapacity existing at the present time in the U.S.A.—about 1 million tons or 33%—most producers expect that this surplus will be taken up within five years and considerably exceeded by 1967. This opinion is based partly on a belief that future applications of nitrogen-based fertilisers (now accounting for at least 75% of synthetic ammonia production) will be greatly increased and will be extended to trees, rivers and inland waters, thus completing a rather unusual nitrogen cycle with crude oil as a point of origin.

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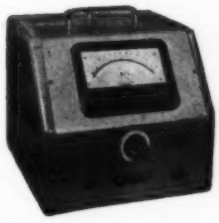

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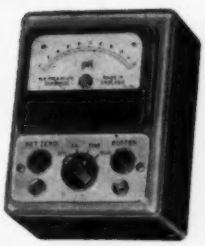

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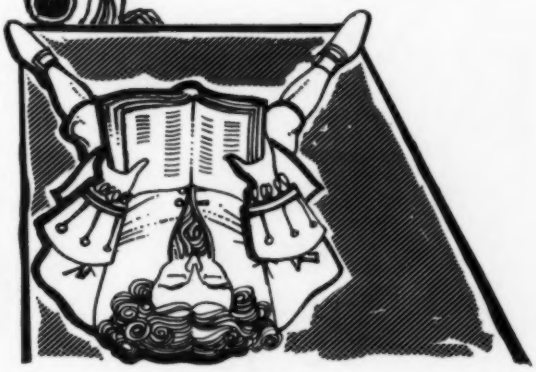

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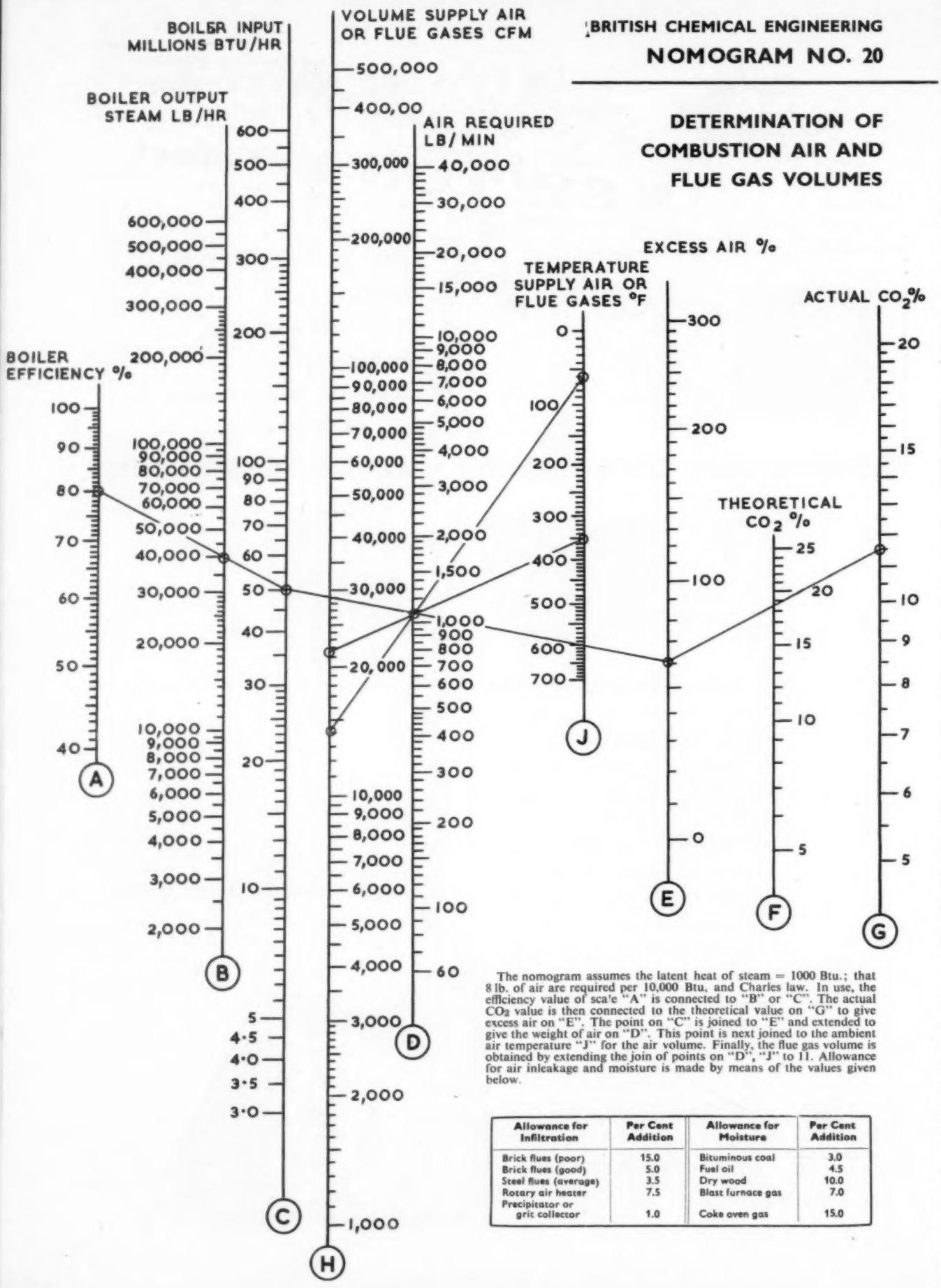
BRITISH CHEMICAL ENGINEERING

NOMOGRAM NO. 20

DETERMINATION OF COMBUSTION AIR AND FLUE GAS VOLUMES



The nomogram assumes the latent heat of steam = 1000 Btu.; that 8 lb. of air are required per 10,000 Btu. and Charles law. In use, the effiiciency value of sca'e "A" is connected to "B" or "C". The actual CO_2 value is then connected to the theoretical value on "G" to give excess air on "E". The point on "C" is joined to "E" and extended to give the weight of air on "D". This point is next joined to the ambient air temperature "J" for the air volume. Finally, the flue gas volume is obtained by extending the join of points on "D", "J" to 11. Allowance for air inleakage and moisture is made by means of the values given below.

Allowance for Infiltration	Per Cent Addition	Allowance for Moisture	Per Cent Addition
Brick flues (poor)	15.0	Bituminous coal	3.0
Brick flues (good)	5.0	Fuel oil	4.5
Steel flues (average)	3.5	Dry wood	10.0
Rotary air heater	7.5	Blast furnace gas	7.0
Precipitator or grit collector	1.0	Coke oven gas	15.0

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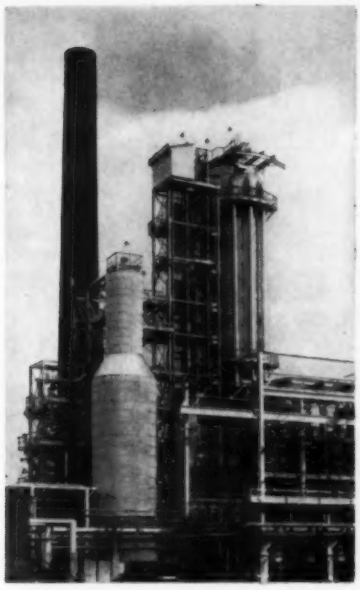
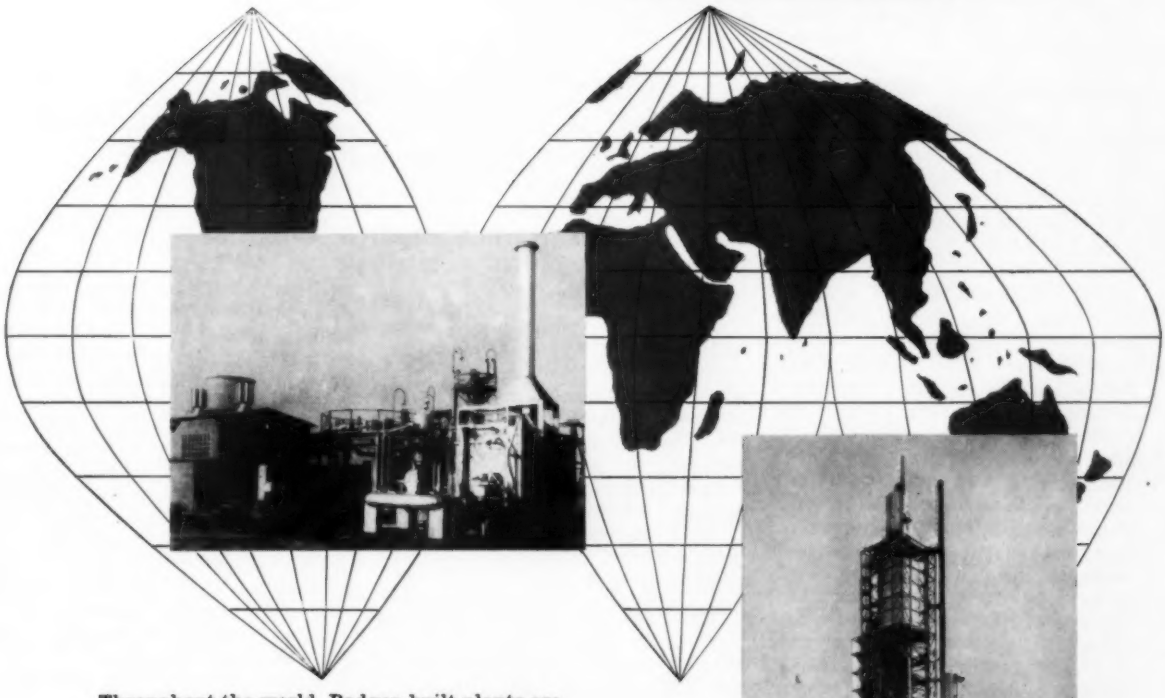
TOMORROW

Throughout the World





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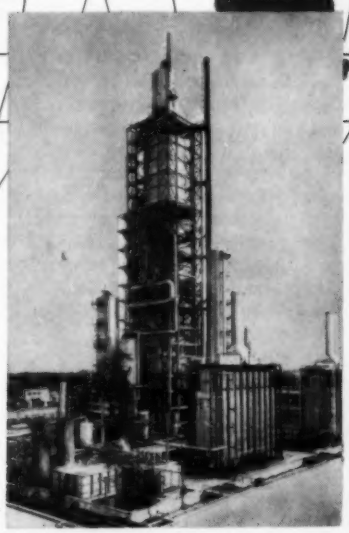

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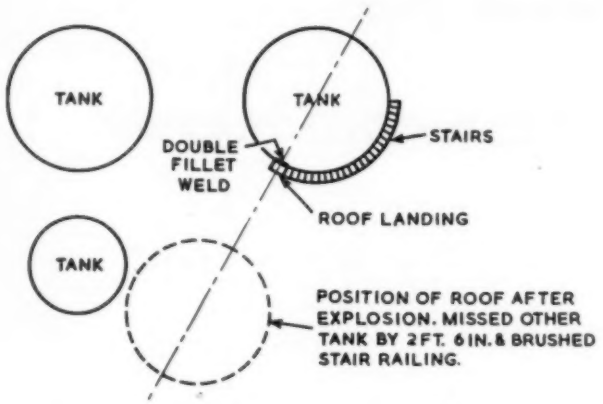
Flight of Tank Roofs

AN UNUSUAL INCIDENT occurred recently at a large chemicals-from-coal plant. In a tank constructed to A.P.I. 12C, which allows for a single fillet weld of tank roof to shell, the contents rose above their flash point in the presence of air. At the point where the roof landing was attached to the tank shell there was a double fillet weld and this had the effect of delaying momentarily the detachment of the roof from the rest of the tank, sufficient to give a well-defined directional effect to the flight of the roof; tests showed that this directional effect could be relied upon and that the landing area could be predicted. As a result, at this plant, tanks have been installed in such a manner that if their roofs are detached through an explosion they land within a predicted area without damage to personnel or to other tanks.



Improving Flexibility in Evaporation

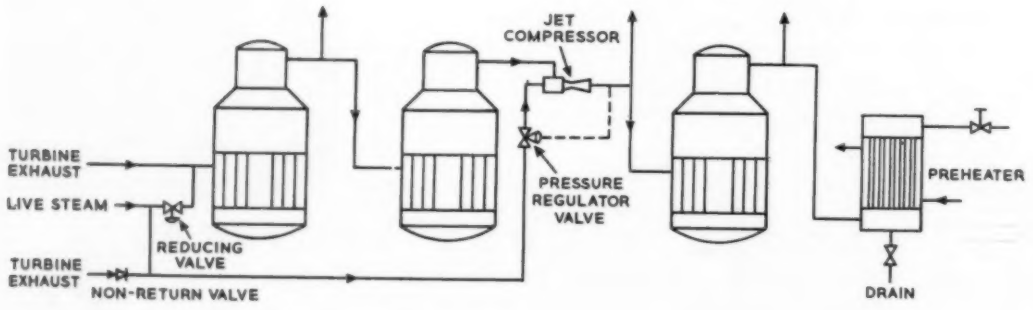
SCALE FORMATION of evaporator surfaces is a factor leading to lower temperature differences between heating steam and the juice under process of evaporation. In beet sugar factories, moreover, it is common for other factors such as steam pressure, density of juice and heat-transfer coefficients to add to the complexity of the evaporation process. In order to prevent reduction of output in pressure evaporators, attempts have been made to maintain temperature differences by means of a pressure controller on the steam supply to the first evaporator. Such measures can only achieve limited success, especially if the main supply of steam is exhaust steam led from the plants' turbines.

The loss of output arising from scale and other factors may be reduced, and in some cases prevented, by feeding steam from the second effect to the suction of a steam jet compressor. The motive steam for the latter will be supplied by boilers or by turbine exhaust. As a result, an increased steam pressure will be provided at the heating surface of the third effect and, therefore, a higher temperature difference.

The maximum effect is obtained when boiler steam is used directly at the compressor, and in some plants this will amount to 12 to 15% of the total supply for evaporation. Exhaust steam may sometimes have to be the pumping fluid at the compressor, and to facilitate changing from one supply of steam to another an arrangement similar to that shown in the accompanying figure is necessary.

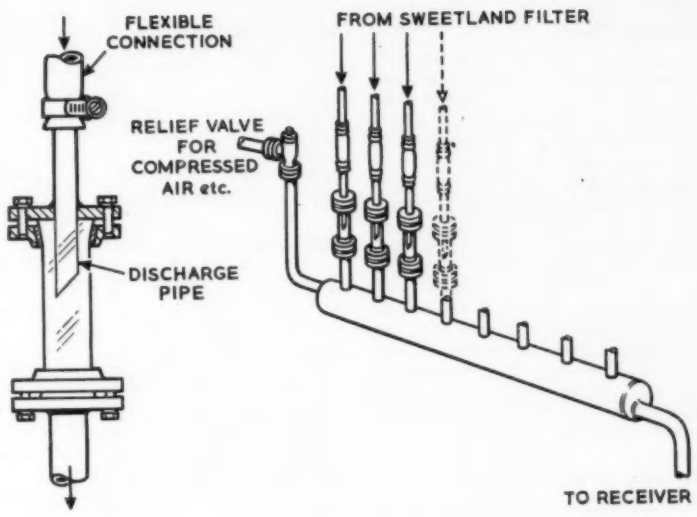
Thus with steam leaving the second effect at 22.5 psig, and high-pressure steam at 514 psig at the compressor, at weight ratio of 4:1, an increase of temperature of 6°C at the steam side of the third-effect heating surface will be obtained. The feed of steam to the compressor can be regulated by a valve governed by the pressure at the compressor discharge.

W.G.C.



Better Sight-glass Layout

FILTER AND WASH LIQUOR from Sweetland filters are normally discharged from the filter leaves by means of individual outlets fitted with sight glasses. This arrangement helps the operator to see when each particular phase of filtration is complete and tells him also if his filter leaves are in good condition. Sometimes better visibility can be obtained by grouping the sight glasses on a manifold and at the same time modifying the sight glass arrangement. In the system shown in the sketch, the filter leaf connections are run via sight glasses into a common main which discharges to the collecting vessels. Compressed air from the cake-drying operation is discharged by means of a relief valve. The discharge pipes terminate in the sight glasses and have their ends cut at an angle. This detail also gives improved visibility in comparison with the sections of glass pipeline sometimes used.



Determining the Solids Content of Slurries

THE METHOD of determining the solids content of a slurry (*British Chemical Engineering*, 1957, **2**, 10, presents several practical difficulties and sources of inaccuracy.

For example, it is difficult to fill a graduated flask exactly to any level, and since it has, as your correspondent says, been found necessary to weigh the flask and its contents to the third decimal place (1 mg) the flask must be filled with an accuracy of approximately 0.001 ml. This is the first practical difficulty encountered in the method. The next is the fact that a micro-balance capable of weighing to 1 mg does not usually provide sufficient room under the beam for the length of a 100-cc flask. Again, the hydrometer method of obtaining the specific gravity of the filtrate is not capable of an accuracy of 0.001, except in the case of special grade hydrometers and only when the surface tension of the liquid is taken into account.

A more satisfactory method for the determination of the solids content of a slurry depends upon the three specific gravities obtained by the gravity bottle method. Then the % liquid is obtained from the following formula:

$$100\left(\frac{AB-BC}{AC-BC}\right) = L$$

where A = specific gravity of solids;
B = specific gravity of liquid;
C = specific gravity of slurry;
and
L = % liquid w/w.

The % solid is, of course, 100 minus this figure.

When necessary, we determine the specific gravity of the solids by the gravity bottle method. A weighed quantity of the dry solid is put into a gravity bottle and the bottle filled with a liquid of known gravity, which will wet but not dissolve the solid. The bottle and contents are then weighed. The following formula gives the gravity of the solids:

$$\text{Specific gravity} = \frac{DS}{DV-W+S}$$

where D = gravity of liquid;
S = weight of solids;
W = weight of the slurry;
and
V = volume of slurry.

100 cc of slurry with between 1 and 10 of solid is a convenient amount to use in most cases.

Due to the ease with which a gravity bottle can be filled accurately, these methods are only dependent upon the accuracy of weighing. Determinations should be made always at the same temperature.

E.H.

Reflux Return on Batch Reactor

IN THE DECEMBER notebook, p. 683, reference is made to a more robust arrangement of glass pipework for the return of condensate to a batch reactor. The loop normally employed was replaced by a vertically mounted tee-pieee with the side branch used for the return of the condensed liquors to the vessel. The glass entry pipe should have been shown projecting below the level of the side arm in order to obtain a liquor seal. The fitting itself should be flange-coupled to the connecting pipework and the drainage cock.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

New Silicate Plant

For sodium silicate manufacture, Joseph Crosfield have installed at their Bow, London, works a furnace and ancillary equipment representing an investment of more than £300,000. The output of the new plant will end the need to transport silicate glass from the company's Warrington works to Bow, and will supply the requirements of London and Southern England which have grown by 300%, the company say, since 1938, when their first silicate dissolver was installed at Bow. Some of the silicate, probably in glass form, will be exported, it is expected, from the London docks. Crosfield's plant, with its new addition, is the only silicate works in the South of England, it is claimed, that can produce both glass and liquor.

Venezuelan Oil Refinery

A new catalytic cracker and a new alkylation plant, each the first of its kind to be built in Venezuela, were commissioned recently at the Cardon refinery on the Paraguana peninsular. The cracker has a capacity of 33,000 barrels a day, and the alkylation plant an initial design capacity of 1,400 barrels a day. Also under construction at the refinery, operated by Compania Shell de Venezuela, is a fourth distillation unit, which will raise Cardon's total capacity to about 300,000 barrels daily. The total cost of the three plants will be almost £30 million.

Direct-process Ethylene Oxide

French and American contracts have been concluded with Scientific Design, New York, for designing plants based on their direct air oxidation process. A plant for Jefferson, to be built at Port Neches, Texas, will produce 60 million lb. a year, and an installation to be erected for Marles-Kuhlmann's at Gonfreville (near Le Havre) will produce 17 million lb. a year. Both are scheduled for operation in 1958. Scientific Design will also now manufacture the patented silver catalyst used in the process for a number of licensees.

Higher Boiling Tar Components

A coal-tar development plant with a capacity for distilling one ton of creosote a day has been commissioned by Koppers at Arroyo, Western Virginia. With it the company proposes to investigate the isolation of the higher boiling components of coal tar and the production of new compounds in sufficient quantities to permit market exploration and development. Engineering and operating data will be collected for possible future use in the design of commercial-scale plants.

Grangemouth Refinery Expansion

Work has started on a £6-million expansion scheme at B.P.'s Grangemouth refinery to increase the processing capacity from 2,200,000 tons to 3,100,000 tons annually. A new crude-oil distillation unit is at present being erected, and associated with this will be a new copper chloride unit, a de-ethaniser, and gas oil and kerosene treatment unit. It is expected that the new distillation unit will be completed early in 1959 and the whole scheme later that year.

Australian Uranium Processing

The first official figures on uranium production at Rum Jungle in the Northern Territory show that the mine treated 71,000 tons of uranium and uranium copper ore in the last financial year, nearly 21,000 tons more than in 1955-56. Production of uranium oxide in concentrates totalled nearly 542,000 lb., nearly 70% more than in the previous year. Australia's output of uranium oxide by 1959 is expected to be about 1,000 tons a year, about one-sixth that of the Soviet Union.

Greek Magnesium Carbonate

The American-Austrian Magnesium Co. has taken over the magnesium carbonate mine in Vavdos-Chalcidice, Greece, in implementation of a recent agreement with the State. Production is expected to start in six months' time with the following output: magnesites 23,000 tons; caustic magnesium 12,000 tons; and enriched chromium 5000 tons, a year.

Chemicals in Rotterdam Expansion

Chemical plant and iron and steel works are to be accommodated in a "Europort" harbour scheme for Rotterdam and Botlek Island, Holland, which is to be put into effect as speedily as possible. In the same area—on the south bank of the waterway connecting Rotterdam with the North Sea—Esso Nederland N.V. is planning to start in 1958 construction of oil-refinery plant having a capacity of 4½ million tons of crude oil annually.

Propellent Manufacturer

A new $3-million solid-propellent plant of Thiokol, at Birmingham City, Utah, was opened recently. Fuel and oxidiser are stored and processed separately and are brought together only when they are ready to be mixed. Mixing bays and final processing areas have frangible walls to direct any explosions away from other buildings.

Lease of Greek Refinery

The Greek oil company Elvyn, which is collaborating with Greek-American oil interests and Esso, has been awarded the lease of the new oil refinery at Aspropyrgos. The plant has a normal capacity of 1,340,000 tons of crude oil a year, which, it is expected, will cover Greek domestic requirements in petroleum products.

New U.S. Rubber Plants

A $22-million butadiene plant, commissioned by Odessa, Butadiene, at Odessa, Texas, recently, has a capacity of 50,000 tons. Of that total, 32,000 tons will be piped to the adjacent synthetic rubber plant of General Tire & Rubber, which has also just been opened. The plant is designed for continuous polymerisation.

Synthetic Petroleum Plant Closed

The first plant to be erected in any country for the manufacture of petroleum and by-products from natural gas —at Brownsville, U.S.A.—is being closed down by its present owners, Amoco Chemicals. They say that, although it is a technical success, it has been economically disappointing.

Dutch Catalyst Factory

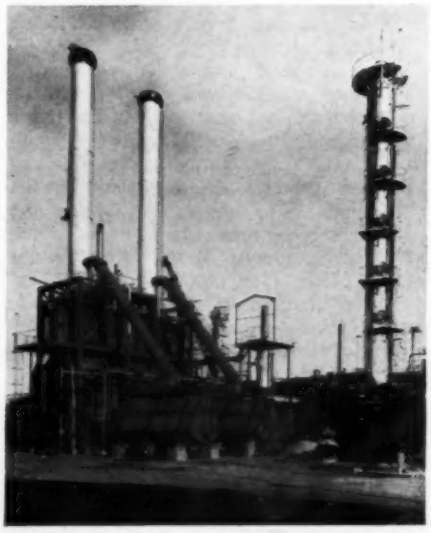
A fourth factory, for the production of oil refinery catalysts, estimated to cost about 8 million guilders (£750,000), is being constructed for Ketjen's Koninklijke Zwavelzuurfabrieken in Amsterdam. It will be operated in conjunction with American Cyanamid.

First Borohydride Plant

A $5.5-million plant for the manufacture of sodium borohydride in Danvers, Mass., has just been completed for Metal Hydrides. It is the first plant to make the product on a quantity basis and the whole of the initial output will be used for military needs.

Knapsack-Bayer Plan

Knapsack-Griesheim A.G. have completed plans for an acrylic nitrile plant, having a monthly production of 600 tons in the initial stage. The entire output will be taken by Bayer for the production of Dralon fibre.



A 4000 B/SD platforming unit under construction, supervised by Procon (Great Britain) Ltd., for DEA, at Heide, Germany. Shown are platformer heaters with unifining unit heaters (centre) and, right, unifining unit column.

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Book Reviews

Automatic Process Control for Chemical Engineers

by Norman H. Ceaglske

John Wiley, London, 1957, 288 pp., 54s.

THIS book forms a useful and much-deserves to be recommended to all books which are available in the field of automatic process control. Prof. Eckman's book[1], first published in 1945, was for a long time the only book available on the subject and today this text could hardly be considered adequate; in the interim, there have been only a few books, of which perhaps A. J. Young's[2] has been the most outstanding.

The present book is divided into seven chapters, of which the first three deal specifically with process control, and the remaining four with the mathematical behaviour of closed-loop systems. Chapter 1 is an introduction; Chapter 2 deals in an illustrative way with a number of measuring systems and then concentrates on the general behaviour of closed-loop process control systems subjected to various combinations of the proportional, integral and derivative control modes, briefly touching in a non-analytical manner on controllers and valves. Chapter 3 commences with a brief description of the Laplace transform and illustrates its use in a simple manner; it then continues to discuss the properties of first- and second-order systems and works out analytically the behaviour of proportional and proportional plus integral controllers. Chapter 4 seems a little out of place in a book of this character, for it is concerned with the solution of second-order systems subject to step and sinusoidal disturbances using classical methods of attack, which seems a pity when the Laplace transform has already been explained earlier. Chapter 5 deals with the reduction of actual systems to equivalent block diagrams and the subsequent mathematical prediction of behaviour under the various control modes of systems subject to desired value and load changes. Chapter 6 deals with the various ways in which the sinusoidal response of the system may be represented. Chapter 7 discusses the question of system stability and the effect on the stability of the various control modes and, rather too briefly, the effect of the various forms of time lags present in process systems.

The book would have been considerably more useful if greater attention had been paid to the analysis of the properties of systems with long time lags, such as thermal processes, and on the other hand with systems of short-time constants such as liquid flow. The last four chapters could equally have found a home in any text-book on servo-mechanisms. Of course, to a certain extent this is unavoidable, since the philosophy is the same, but such differences as time scale and disturbance reversals, such as are brought about in exothermic reactions, would have made for more interesting reading.

The book can be confidently recommended as an introductory text-book for students commencing the study of automatic control in chemical processes.

G. L. D'OMBRAIN.

[1] Eckman, D. P. "Principles of Industrial Process Control", John Wiley & Co. Ltd., London, 1945.

[2] Young, A. J. "An Introduction to Process Control System Design", Longmans, Green & Co. Ltd., London, 1955.

Statistical Methods in Research and Production, with Special Reference to the Chemical Industry, third edition

Editor: Owen L. Davies, M.Sc. Ph.D.

Oliver & Boyd, London, 1957, 396 pp., 45s.

THIS is an excellent handbook which deserves to be recommended to all whose business it is to draw conclusions from numerical data. The authors have had practical experience in handling the wide range of statistical problems arising in the chemical industry and, more important, they have had experience in explaining them to chemists. The usefulness of the book is therefore not academic, but has been proved in the exacting laboratories of Imperial Chemical Industries Ltd.

The book is intended for those who want to seize the fundamental principles of applied statistics, as well as the details of its application, but who do not wish to pursue mathematical rigour and complexities. In so far as this is possible, the authors have succeeded. The presentation, therefore, rests on appeals to intuition and no attempt is made to justify the procedure recommended. For example, the mean of a population is given mathematical definition in a footnote only and the theorem that the sample mean tends in probability to the population mean is merely stated.

Normally, this unrigorous approach is considered dangerous for students, but here the pitfalls which await them are so clearly illuminated that the readers of this book can be confident that they will at least recognise when they are in need of expert advice. For much of their day-to-day work this book contains all the advice they need. The examples are practical and the advice on computation (sorely needed by beginners) is comprehensive and to the point.

Some of the traditional difficulties are particularly well treated, such as the difference between the models available in regression and correlation situations and the logic of assessing "significant" results. On the other hand, the book is over-careful to avoid any hint that there may be controversy between professional statisticians. This reticence by doctors naturally reassures the patient, but if he started to treat himself he might well benefit from some warnings. For instance, mention of fiducial limits or of work on the ratio of estimated parameters does not include the message that there are different opinions on these subjects.

The second edition of this book was published in 1949, but much has been added since then. The first three chapters introduce the subject and describe distributions and measures of location and dispersion. Chapter 4 discusses confidence limits, which are given more emphasis than tests of significance. This is reasonable, since in much research and plant work the data being analysed are only part of the material leading to a decision, and the function of statistics is rather to describe the data and to summarise what they imply than to be a machinery for taking the decisions.

The decision-making function of statistics is mainly shown in the last two chapters of the book, on control charts and acceptance sampling schemes. It is also exemplified in Chapter 5, on choosing the optimum number of observations in a statistical test, which describes clearly some new work by Grundy, Healy and Roes. The ideas of cost and of the prior distribution of parameters enter explicitly here and some readers will find this the most rewarding section of the book. Finally there is a chapter on the analysis of variance, two on linear, multiple and curvilinear regressions and one on discrete variables and contingency tables.

S. R. BROADBENT.

Regression Analysis of Production Costs and Factory Operations, third edition

by Philip Lyle

Oliver & Boyd, London, 1957, 204 pp., 16s.

THE third edition of Lyle's book is almost the same as the second or 1946 edition. L. H. C. Tippett has written some interpolations and a short preface, in which he suggests that a more completely revised edition is contemplated. The growth of cost accountancy, of "scientific" management and of procedures which aim to minimise overall cost all emphasise that the relation of costs to factory operations is of the first importance. In many cases this relation is best exposed by statistical regression analysis. For these situations Lyle has written an elementary and clear approach to correlation, covariance and regression.

Cost may be measured in other than direct monetary terms: time, manpower and raw material usage are all susceptible to this type of analysis. In fact, the picture facing the title page of this book is a photograph of a chart of steam consumption against output, displayed in a boiler house. Further, the technique is of much wider application than the field of factory operation, and anyone faced with a regression situation may find this introduction useful. Lyle has also introduced related topics, such as index number, unit and marginal costs, which applications in economics may require.

The approach is perhaps less sophisticated than that of the I.C.I. authors, and the pitfalls are not so clearly defined. For example, recent papers by M. G. Kendall, Lindley and R. L. Brown, which show how difficult this problem can be, are not mentioned. The bibliography would be more helpful if it were expanded and collected in one place rather than scattered in footnotes.

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The discovery of an entirely new synthetic method for the production of valuable chemicals is a rare event usually followed by many research papers, especially from academic sources. The oxo reaction for the production of aldehydes and alcohols from olefins, carbon monoxide, and hydrogen, has been little noted except in the patent literature, and a few papers related to the catalyst or the reaction mechanism. The purpose of this book is to review the patent literature on the oxo process and to present added information about the most important derivatives of the process—the higher oxo alcohols.

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Consultant on Industrial Safety, Nuclear Development Corporation of America

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This volume is the successor to the same author's *Handbook of Dangerous Materials*, and is, in effect, an entirely rewritten and greatly expanded version of the original work. Every aspect of industrial safety is included, and arranged for practical use. This is likely to be the most useful and complete book on industrial safety yet published.

37 ESSEX STREET, LONDON, W.C.2

PLANT EQUIPMENT NEWS

Temperature-sensitive Bellows

Longworth offer, for fitting into customers' equipment, an ether-filled temperature-sensitive bellows unit which was recently developed for the operation of a valve in a piece of medical apparatus. It is intended for use between temperatures of 5°C to 50°C with a gradient of 0.01095 ±0.00015 in. per 1°C between 15°C and 35°C. The instrument has a total movement of about half an inch. Each unit is dispatched with an individual test note of performance. **Longworth Scientific Instrument Co. Ltd., Abingdon, Berks.**

BCE 2432 for further information

Plastic-coated Steel

Workable P.V.C.-coated steel-sheet is being produced by John Summers. Developed exclusively by them in conjunction with B.X. Plastics, Stelvetite, as it is known, is strip mill cold-reduced steel having a coating of specially formulated Velbex P.V.C. The reverse side of the sheet may be either a bonderised steel or electro-zinc-coated surface. The product can be bent, formed, seamed, deep drawn, joined and welded without damaging the coating; it has excellent electrical insulating properties and is highly resistant to acids, alkalis, greases, detergents, weather, humidity and to abrasion, the makers say, in addition to being warm to the touch. It does not support combustion, and is stable at higher temperatures than P.V.C. alone. The steel gauges in which it is available are 26G to 16G, in sheet lengths and widths of up to 144 in. and 48 in. respectively. The P.V.C. coating is 0.014 in. thick. It can be supplied in almost any colour, in a range of embossings. **John Summers & Sons Ltd., Shotton, Chester.**

BCE 2433 for further information

New Geiger Counter Tube

A new Geiger counter tube, type GM.4LB, with an extremely low rate of count in the absence of the test specimen has been developed by G.E.C. for the measurement of minute amounts of radioactivity. The tube must be operated in a heavily-shielded enclosure and surrounded by a ring of gamma counters. Background responses as low as 0.4 counts per minute have been obtained. The company is also marketing two new non-corrodible lighting fittings designed for use in food factories and other installations where corrosive vapours are present. A new method of suspension is used, and the fittings are made largely of plastic and have no external metal work. **General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.**

BCE 2434 for further information

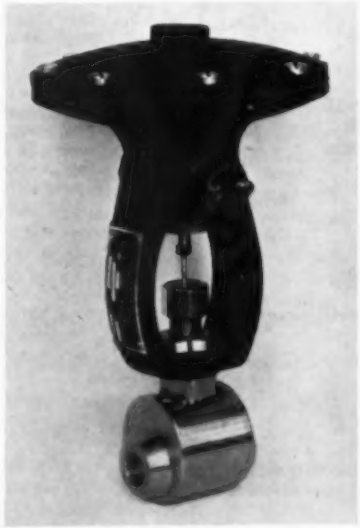
Sanitary Pipe Fittings

A new range of stainless-steel sanitary unions, Metior C.I.P., made available by Talbot, is of simple design and is suitable for use where cleaning-in-place techniques are employed. Its features include a flat sealing ring and flush face fitting of tube and liners. The range is intended particularly for dairying, brewing and food pipe-lines. **Talbot Stead Tube Co. Ltd., Green Lane, Walsall.**

BCE 2435 for further information

Diaphragm Control Valve

Crosby are now manufacturing the Masoneilan type 107/108 diaphragm-operated control valve designed for use with exceptionally small flows. Intended for pilot plant and dosing operations, it is made with an 18/8 stainless-steel Barstock body rated at 6000 psi, and ¼-in. female connections which can be screwed B.S.P. or A.P.I. The body is available with alternative size trims down to a minimum having a flow coefficient of 0.07. The diaphragm superstructure,



which is designed for 3-15 psi air pressure, is of aluminium alloy and can be supplied to give either reverse or direct action. The diaphragm is of nylon-reinforced Neoprene. **Crosby Valve & Engineering Co. Ltd., Crosby Works, Ealing Road, Wembley, Middlesex.**

BCE 2436 for further information

Resin-impregnated Tanks

Vinaglas are making available resin-impregnated fibre vessels having an inner surface of a chemical-grade rigid P.V.C. bonded to the shell. The vessels, the makers point out, possess considerable acid- and alkali-resisting properties and resistance to mechanical damage. The tanks can be made to the user's specification in dimensions up to, at present,

5 ft. **Vinaglas Ltd., Stockingswater Lane, Enfield, Middlesex.**

BCE 2437 for further information

Liquid Transfer

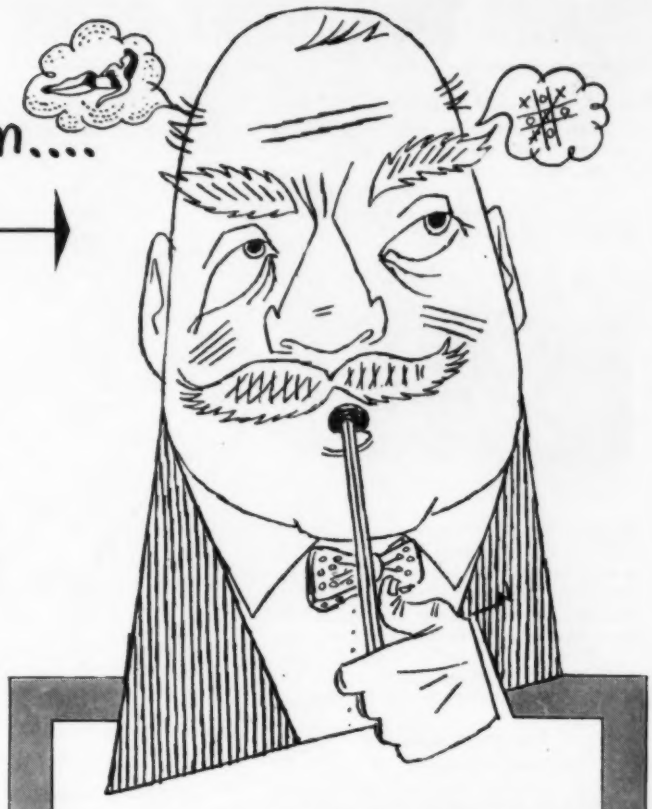
For transferring liquid or suspensions containing costly materials or substances that will be adversely affected by heating, shearing or agitation, Watson-Marlow have produced a transfer equipment known as the Watson-Marlow vessel pump. It consists essentially of a vessel capable of withstanding vacuum and pressure and fitted with a patented device to control the generation of pressure or of vacuum. The change from one pressure state to the other is affected by moving one handle. The vacuum is created by a flow of air or gas through a venturi exhauster, and the pressure is produced by diverting the gas directly to the vessel. The consumption of gas will not normally exceed 2 cu. ft/min. The plant may be modified by introducing the pressure gas through jets at the bottom of the vessel so that the contents can be mixed. The equipment can therefore be used for bulking mixing and dispensing. **The Watson-Marlow Air Pump Co., 68 Dedmere Road, Marlow, Bucks.**

BCE 2438 for further information

Pneumatic Timer

Designed primarily for the control of reflux-ratio on distillation columns where the top product of the column is switched from make to reflux at regulated time intervals, the new Sunvic pneumatic timer is basically a simple resistance-capacity oscillating circuit, generating a triangular wave-form signal. This signal is chopped at adjustable amplitude levels to give the on/off periods required. No electrical power is used in the instrument's operation, so that the timer is flameproof. Other applications include control of blasts on water-gas generators and control processes using solutions. The oscil-

We solved an 'insoluble' problem....



. . . and lowered the cost of producing caustic soda.

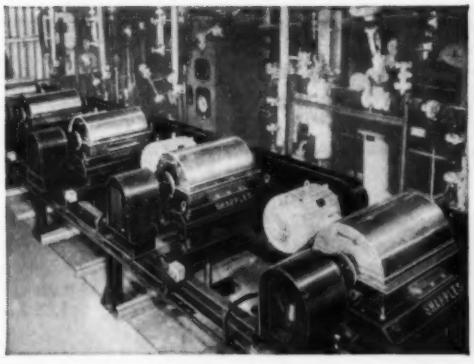
One of the main problems of caustic soda manufacture by the electrolytic method using diaphragm cells is the separation of salt from the caustic soda solution and the elimination of sodium sulphate. We knew that in a high gravitational field 'insoluble' sodium sulphate becomes soluble in brine. We knew that they found it expensive to purge their salt of sodium sulphate by existing methods. So we suggested centrifuging the salt with brine in the Sharples Super-D-Hydrator, using a special automatically controlled diversion valve to keep the mother liquor separate from the brine wash liquor.

The result was a higher purity of sodium hydroxide, as well as the separation of a pure sodium chloride, extremely low in sodium sulphate and sodium hydroxide, and a small volume of brine containing a high concentration of sodium sulphate. Less refrigeration was needed to precipitate this from the smaller amount of brine (reduced cost 1).

The time taken for the removal of the sodium sulphate was reduced from a matter of hours to about 10 to 15 seconds (reduced cost 2). Other advantages resulting from this made it possible to modernize the complete process of caustic soda production by the electrolytic method. Savings of 15% in direct operating costs were the total result of calling for Sharples.

This is a good example of the way the world-wide Sharples Centrifugal Engineering Service can help you solve a separation problem by the most efficient method. Sharples can offer you a complete range of centrifugal machines for any separation purpose.

Write to us and we'll be glad to send you a copy of our Bulletin No. 3054M–The Super-D-Hydrator. Or, if you wish, 'phone Camberley 2601 and talk to Martin Trowbridge about your problem.



An Installation of Sharples Super-D-Canters installed at one of the factories of Courtaulds Limited.

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PLANT EQUIPMENT NEWS

lating circuit has a period adjustable by a knob from nominally 5 seconds to 5 minutes. A second knob adjusts the ratio of on to off times (or vice versa) from 30 : 1 to 1 : 4. Since the timer has no moving parts, and the whole circuit is under air pressure, it is of value, it is

pointed out, in corrosive or dusty atmospheres. The company is also producing a relay for use with data-logging machines, which multiplies, divides and carries out square-root calculations. It is therefore particularly useful in linearising readings on flows, etc. **Sunvic Controls Ltd., P.O. Box 1, Harlow, Essex.**

BCE 2439 for further information

Operation Recorder

A recorder originally designed by Fielden for use with a smoke-emission detector is now being made generally available for a variety of recording operations. It may be supplied with a twenty-four-hour chart or a seven-day chart. Each is of a specially-prepared heat-sensitive paper and is marked indelibly in use by a heated stylus. The instrument is supplied in a die-cast aluminium case. **Fielden Electronics Ltd., Wythenshawe, Manchester.**

BCE 2440 for further information

Vacuum Pump

A small two-stage Roots pump, Ruvac Z05, for the production of low pressures, is being made available in Great Britain by Leybold. Its displacement is about 70 m³/hour, and the ultimate pressure obtained is less than 2×10^{-4} mm. Hg. Its dimensions are 208 mm. × 300 mm. × 570 mm. For use on vacuum equipment the company is supplying Corrilen protective coating, which is said to be water-repellent, free of pores, adhesive, easy to clean, compatible with solvents and unaffected by large temperature variations (−180° to +200°C). **Leybold Vacuum Sales Ltd., 27 Broadwick Street, London, W.1.**

BCE 2441 for further information

Electrical Measurement

Avo have introduced a pocket-sized instrument, the Multiminor, for the measurement of a.c. and d.c. voltage, d.c. current and resistance. It replaces the company's Universal Minor models 1 and 2, and provides, in particular, higher sensitivity (10,000 ohms/volt), increased ranges, and control by a single range-switch. The instrument has nineteen ranges and two scales—for, respectively, current and voltage measurement, and resistance measurement. **Avo Ltd., 92 Vauxhall Bridge Road, London, S.W.1.**

BCE 2442 for further information

Ultrasonics Transformer

Kerry's Ultrasonics have elaborated in their new Harold Hill factory an ultrasonics transformer for thread cutting which makes use of ultrasonic anti-nodal points generated in a horizontal plane and converts them into a "reciprocating, piston-like movement in the vertical plant", limited, it is said, only by the mass of materials and the input power used. To attain a greater amplification of the tool movement the company has experimented with a hydraulic transducer. They report that an apparently molecular change took place in oil that, at a pressure of about 20,000 psi, was subjected to ultrasonic power, and they expect that further experiments will reveal new uses for ultrasonics in this direction. The company is now in full production of cabinet ultrasonic-cleaning machines for operation at one megacycle and 20 kilocycles per second. **Kerry's (Ultrasonics), Ltd., Harold Hill, Essex.**

BCE 2443 for further information

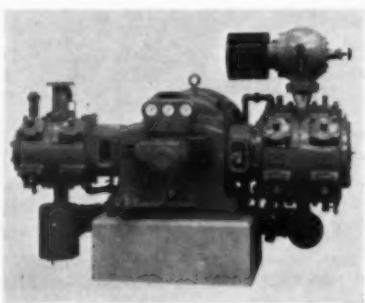
Perspective-drawing Machine

Recently made available in Britain is the Swedish Autoperspect apparatus designed to enable an operator easily to produce perspective drawings of an object from a plan and elevation. The scope of the apparatus is said to be virtually limitless, as any kind of perspective from any angle of view may be drawn with it. Cut-away, exploded and stereoscopic views fall within the machine's range. Drawing time can be reduced by up to one-ninth over that taken by conventional methods, it is claimed. **Autoperspective Ltd., 5 Victoria Street, London, S.W.1.**

BCE 2444 for further information

Horizontal Air-compressors

Alleys, makers of horizontal-balanced opposed compressors since 1950, have introduced a new range, series 56 B.9, having two horizontally-opposed cylinders. All reciprocating parts are designed so that opposing weights are equal, and the machines, the makers say, are smooth



running and almost vibrationless. Connecting rods are dropped stampings with the big ends fitted with precision bearing shells. The crankcase is a rigid box-section Meehanite casting into which are fitted replaceable crosshead guides. The electric motor rotor is fitted directly to the solid crankshaft and also serves as a flywheel. In setting up the compressor in the field, therefore, all lining up is eliminated. The range includes single- and two-stage compressors available in capacities up to 2000 cu. ft a minute. **Alley & MacLellan (Polmadie) Ltd., Glasgow, S.2.**

BCE 2445 for further information

Diaphragm Air Compressor

The latest model of the Compton range of diaphragm air compressors is equipped with fan cooling and has been given the designation type D series 3. The mechanical cooling produces a notable reduction in the running temperature of the compressor, it is said, and gives an extended life to the diaphragm. The makers recommend it with confidence for continuous

duty at pressures up to 40 psi, or for intermediate duties at higher temperatures. **Dawson, McDonald & Dawson Ltd., Compton Works, Ashbourne, Derby.**

BCE 2446 for further information

Carboy Pump

The Placid pump by E. M. Francis has been designed to enable small quantities of liquid to be readily withdrawn from carboys and other containers. It can be used with any vessel having an opening or neck at least 1½ in. in diameter and not being deeper than 23 in. The appliance operates by means of a rubber bulb, which does not normally come into contact with the liquid. **E. M. Francis Ltd., Mortimer House, Linton, Cambs.**

BCE 2447 for further information

Air Ejector

Nash Engineering have introduced the Nash air ejector, which employs atmospheric air as its motivating medium. Used in conjunction with a two-stage vacuum pump, it is suitable for duty

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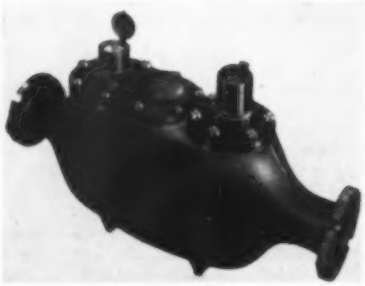
PLANT EQUIPMENT NEWS

in the pressure range of 1.5 to 0.5 in. Hg absolute, with an average shut-off pressure of 6 mm Hg absolute. The combination, it is claimed, results in large evacuating capacity with relatively high ultimate vacua, together with the accepted advantages of liquid ring vacuum pumps. It is suited for batch and continuous drying, evaporation, sugar refining, distillation, main condenser exhaust service, etc. **Nash Engineering Co. (Great Britain) Ltd., Hytor Works, Commerce Way, Purley Way, Surrey.**

BCE 2448 for further information

Water Meters

George Kent announce the introduction of a new range of compound trade water meters, for use with widely varying cold-water flows. They embody separate measuring units—one for high and one for low flows—and an automatic change-over valve to select the unit required. The complete instrument is contained in a single housing. The meter is manufactured in 3-in. and 4-in. pipe-



line sizes, the 3-in. size, for example, being able to cope with a variation in flow rate of 500 : 1 with an accuracy of ±2%. **George Kent Ltd., Luton, Beds.**

BCE 2449 for further information

Sump Pump

After supplying to the Central Electricity Authority a number of submersible sump pumps designed for use with unscreened water and the movement of solids in suspension, British Pleuger have incorporated that design in their standard production range, and the models being made at present are suitable for the capacities 2000-9000 gallons per hour with heads of up to 90 ft. Larger units are under construction. The pump is of the centrifugal type, is described as unchokable and is connected directly to the submersible motor. The motor is water filled for lubrication and cooling and can run on snore. **British Pleuger Submersible Pumps Ltd., Station Road, Coleshill, Birmingham.**

BCE 2450 for further information

Resistance Thermometer Controller

The Foster resistance thermometer controller, model 3510, has been designed to operate for the temperature range −50°C to +350°C in conjunction with the company's fast-response thermometer elements. All resistances comprising its Wheatstone bridge system are accurately calibrated and aged to eliminate control-point drift. The control operates on a

differential of 0.1°C, but can be detuned simply to operate on wider differentials (up to 50°C) if required. **Foster Instrument Co. Ltd., Letchworth, Herts.**

BCE 2451 for further information

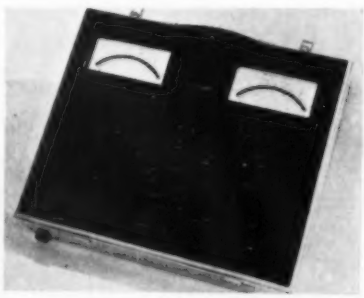
New Computer

I.B.M.'s new electronic data-processing system—705 model 3—will reduce the calculating time on many applications by, it is said, as much as 40%. One of the computer's important new features is the very high-speed magnetic tape unit which can read or write information on magnetic tape at the rate of 60,000 characters per second. Each reel of magnetic tape can now hold as much as three times the amount of information that could formerly be stored. If two or more data synchronisers are used, the instrument can read, write and compute simultaneously. A magnetic core memory which can be enlarged to accommodate up to 80,000 characters has also been incorporated. **I.B.M., United Kingdom, Ltd., 101 Wigmore Street, London, W.1.**

BCE 2452 for further information

Corrosion Test Set

The Mark II Multi Combination test set being supplied by Mapel has been designed to undertake all electrical measurements normally required for field

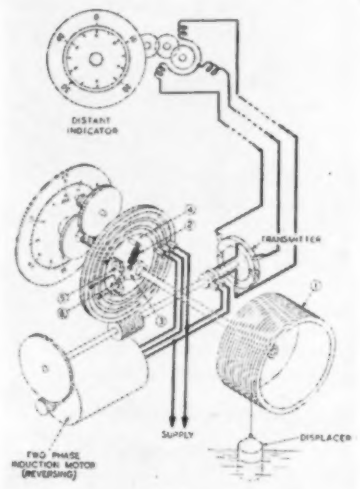


work in corrosion investigation and cathodic-protection testing. A selector switch enables the change from one kind of arrangement to another to be made easily. The set, which is built into a single robust case, is light and compact and is supplied with two hand-calibrated scales drawn to match the current characteristics of the particular set. The instruments included in the set are a low-resistance millivolt voltmeter; a high-resistance voltmeter and a d.c. biasing potential which can be used in series with it; a potentiometer voltmeter; and a milliamp-ammeter. **Metal & Pipeline Endurance Ltd., Artillery Mansions, Victoria Street, London, S.W.1.**

BCE 2453 for further information

Tank Gauge

The new Evershed Precise tank gauge can be fitted to either fixed or floating roofed tanks and provides local and distant indication of levels. The null-point displacement transmitter is operated by the displacement of a float suspended from a winding drum and supported partly by the liquid and partly by a helical spring. One end of the spring is attached to an arm rigidly fixed to the spindle of the winding drum; the other is attached to a disc carrying two contacts. Changes in level bring the centre contact into touch with an outer contact. A reversible motor is thereby operated, and thus causes the



disc to follow the movement of the winding drum until the centre contact is again free. **Evershed & Vignoles Ltd., Acton Lane Works, London, W.4.**

BCE 2454 for further information

Other Items of Interest

The following spray-coating dispersions have been added to the Fluon P.T.F.E. range: dispersion primer PI and acid solution B; clear FI; black FI; and white FI. **Imperial Chemical Industries Ltd., Millbank, London, S.W.1.**

BCE 2455 for further information

Baker's are making available a polygon-shaped platinum crucible for which the advantages of greater stability and

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That, in effect, happens when secondary heat is lost in effluents, vapours and products. Industry cannot afford this loss today—and it is unnecessary. APV have types of heat exchangers to meet almost every requirement and capable of high rates of heat recovery even from sources often regarded as uneconomic.

The **APV PARAFLOW PLATE HEAT EXCHANGER** has overall liquid/liquid coefficients ranging up to 700 B.T.U./Sq. ft. h., °F. and its stainless steel plates make it ideal for potable and corrosive liquids. It combines the advantages of compactness and flexibility with full accessibility and easy replacement of liquid-bearing surfaces.

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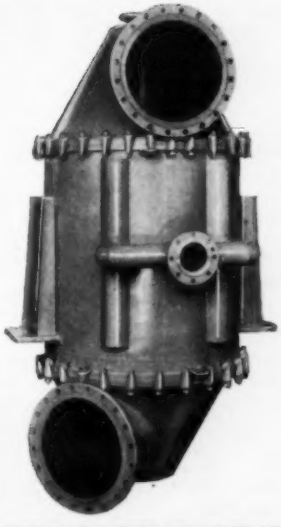

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PLANT EQUIPMENT NEWS

greater ease of handling over the conventional, round design are claimed. **Baker Platinum Division, 52 High Holborn, London, W.C.1.**

BCE 2456 for further information

New chemically-inert papers, Seven O, Sized neutral papers, offered in sheets, in bulk, or made up into Palfsacks are now available from William Palfrey. The papers, which were developed in association with the U.S. Navy for use in contact with metals, are said to be particularly suitable for use with steel, copper, tungsten, aluminium, nickel, brass, manganese, zinc and cadmium. **William Palfrey Ltd., 24 City Road, London, E.C.1.**

BCE 2457 for further information

The MY series of heating mantles recently introduced by Electrothermal is a simplified version of the company's M series. The new mantles are fitted in cylindrical aluminium housings with detachable bases. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 2458 for further information

A new miniature ¼-in. glandless gas-valve which will handle gases of pressures up to 100 psi, and which is suitable as a pilot gas-valve on automatic industrial gas burner installations, is being made by **Black Automatic Controls Ltd., Leafield, Corsham, Wiltshire.**

BCE 2459 for further information

Baldwin have introduced a system of multi-point control valves for low-pressure fluid-power uses. The valves, which may be fitted with manual, mechanical, electric solenoid or pilot operating mechanisms, are supplied as a multi-point unit. Any number of valves up to twelve can be embodied. **Baldwin Instrument Co. Ltd., Brooklands Works, Dartford, Kent.**

BCE 2460 for further information

Evans Electroselenium announce that their Eel P.R.U. densitometer conforms exactly to the specification detailed in Section 2 of British Standard 2831, 1957, "Methods of Test for Air Filters used in Air Conditioning and General Ventilation". **Evans Electronselenium Ltd., Westminster Bank Chambers, Bishop's Stortford, Herts.**

BCE 2461 for further information

Chemical- and corrosion-resistant cable conduits and fittings in plastic (P.V.C.) are being made by **Ega Electrical Ltd., Holyhead Road, Wednesbury, Staffs.**

BCE 2462 for further information

Bitugell, a heavy-duty anti-corrosive compound developed by Evode, provides a protective film of up to 0.03 in. thickness in one coat. A corrosion inhibitor is incorporated in the formulation to prevent rust creep from damaged areas. Suggested applications include coal washing machinery; coking plant; sulphate plants; water tanks (excluding drinking water containers); coal and coke conveyors; and other equipment in coal, coke, gas, steel and petroleum industries. **Evode Ltd., Common Road, Stafford.**

BCE 2463 for further information

English Electric are now manufacturing two new types of relay case, one dust-proof and the other completely sealed. In the dust-proof cases, breathing is effected through a filter containing a replaceable unit of shredded nylon. Iron particles are trapped by a magnetised grating in the cap of the filter. The sealed cases are covered with plastic for protection against corrosive atmospheres, and contain a silica-gel indicator close to the glass to give visual warning of a leak. **English Electric Co. Ltd., Stafford.**

BCE 2464 for further information

Gasket shields of P.T.F.E. are being made by Dunlop for use on glass piping that handles corrosive liquids. The new shields, consisting of a thin P.T.F.E. envelope, protect the bore and both faces of the rubber gaskets, without detracting from the gaskets' resilience. **Dunlop Rubber Co. Ltd., St. James's Street, London, S.W.1.**

BCE 2465 for further information

Pneubin pulsating panels, made of steel-backed neoprene and operated by pneumatic inflation and deflation, for the prevention of clogging of bins and hoppers are available from **Patterson House Engineering Co. Ltd., Bedford Street, London, W.C.2.**

BCE 2466 for further information

New Publications

The range of static and dynamic pressure seals manufactured by Bell's are described in a new publication, "Bestobell Packings". The packings described form a seal by circumferential pressure. **Bell's Asbestos & Engineering Ltd, Bestobell Works, Slough, Bucks.**

BCE 2467 for further information

Dust collection and control plant manufactured by the Gas Cleaning Division of W. C. Holmes is described in the recently produced Publication No. 72 by **W. C. Holmes & Co Ltd., Turnbridge, Huddersfield.**

BCE 2468 for further information

Publications No. 572 and 573 give details of the Audco remote control and Audco electrically-operated valves now being marketed by **Audley Engineering Co. Ltd., Newport, Shropshire, England.**

BCE 2469 for further information

Paterson Hughes have just issued a series of brochures on their handling equipment. Copies of the series, which include goods handling schemes, foundry mechanisation, conveyors and elevators, electric hoist blocks and runways and miscellaneous handling equipment, may be obtained from **Paterson Hughes Engineering Co. Ltd., Bedford House, Bedford Street, London, W.C.2.**

BCE 2470 for further information

Detailing the Buell Micro-Lector (Van Tongeren) system of dust collection and fly ash elimination is a recent publication by **Buell (1952) Ltd., 3 St. James's Square, London, S.W.1.**

BCE 2471 for further information

Three new publications (986, 150 and TP 5022/957) have been received from Kent. Instrumentation is the theme of 986 and 150, the former dealing with a particular automatic control plant designed by Kent for the Highfield Power Station, South Africa, and the latter deals with the plate-type and unit-type instrument panels. The last-named publication is reprinted by Kent with the permission of The Gas Council, and deals with the control of flame characteristics. **George Kent Ltd., Luton, Bedfordshire, England.**

BCE 2472 for further information

A recent publication by Whiffen & Son gives details of their product hydrazine and its use for the deoxygenation of boiler-feed water. Copies from **Whiffen & Sons Ltd., Fison House, 95 Wigmore Street, London, W.1.**

BCE 2473 for further information

"The Climbing Film Evaporator" is the title of a new brochure from the Q.V.F. stable. The unit described has a single 1-in. bore calandria tube, 10 ft long, and is suitable for operation at either atmospheric pressure or under vacuum as a single-pass or recirculation unit. Catalogue No. is CFE/1. **Q.V.F., Duke Street, Fenton, Stoke-on-Trent, England.**

BCE 2474 for further information

A technical publication, "The Nimocast Alloys", contains reports on some of the tensile, impact, hardness and rupture properties of six alloys in the Nimocast series. **Henry Wiggin & Co. Ltd., Wiggin Street, Birmingham, 16.**

BCE 2475 for further information

Corrosion problems and their solution have long been of special interest to Acalor. Their latest brochure on their range of plant for use in highly-corrosive situations illustrates how successful this company upholds its claim to be the corrosion specialists. **Acalor (1948) Ltd., Kelvin Way, Crawley, Sussex.**

BCE 2476 for further information

An illustrated 22-page booklet explaining the uses of Polyzote in thermal insulation and moulding and describing methods of working the product has been published by **Expanded Plastics Ltd., 675 Mitcham Road, Croydon.**

BCE 2477 for further information

The advantages of wet dedusting, the principle of operation of Dallow Lambert equipment for this process and its construction are described in illustrated catalogue No. 50 published by **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 2478 for further information

Special announcement

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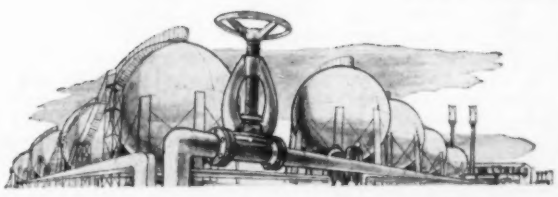


Butterworths Scientific Publications
88 Kingsway, London, W.C.2

Month's News in Brief

The majority of members of the Association of British Chemical Manufacturers, as shown by a recent referendum, is in favour of participation in a European Free Trade Area subject to the safeguards of the Government's policy. The two safeguards that the industry feels are of particular importance are a strengthening of U.K. anti-dumping legislation and the incorporation of a value criterion (rather than a process basis) into any "country of origin" clause. At present nearly one-quarter of U.K. exports of chemicals is to the likely members of the Free Trade Area.

Britain's first export operational atomic power-station is to be supplied to the Italian State-controlled corporation, A.G.I.P. Nucleare, by the Nuclear Power Plant Co., Knutsford, Cheshire. The contract is expected to be worth about £20 million, including the initial fuel charge. The station, to be built in Northern Italy, will have a capacity of about 200 megawatts. It will possess only one reactor, running on natural uranium fuel graphite moderated, and having a carbon-dioxide gas heat-transfer system to produce steam in probably six boiler units.

To obtain more power for titanium manufacture at the Kynoch Works, Birmingham, of the Metals Division of I.C.I., and to reduce to a minimum the emission of smoke and dust over the surrounding semi-residential area, a cyclone-fired boiler by Babcock & Wilcox—the first of its type to be brought into operation in this country—has been installed. On test the dust burden of the chimney gas had been shown to be less than 10% of the generally-accepted standard of dust emission.

The Du Pont Co. (United Kingdom) Ltd., 5 Charles II Street, London, S.W.1, has been formed to manufacture and sell neoprene in the United Kingdom and European markets. It is a wholly-owned subsidiary of E. I. Du Pont de Nemours & Co. Inc. With effect from January 1, 1958, sales for neoprene will be made in the name of Du Pont Co. (United Kingdom) Ltd., and Durham Raw Materials Ltd. will act as sales agents. From January 1, 1959, Durham Raw Materials Ltd. will surrender the agency and Du Pont Co. (United Kingdom) Ltd. will assume full control of all neoprene sales.

Planning permission for the construction of an oil refinery for Esso near Milford Haven has been granted by the Minister of Housing and Local Government and the Minister for Welsh Affairs. The refinery, which is likely to be completed by 1960, will comprise a plant to process 100,000 barrels of crude oil per day.

The Institute of Fuel has been admitted to membership of the British Nuclear Energy Conference.

B.P. have moved their geophysical and petroleum engineering research station from Kirklington Hall, near Nottingham, to a specially-built laboratory at Sunbury-on-Thames, and have thereby concentrated most of their research at Sunbury.

L. A. Mitchell Ltd. have opened a London office at Portland House, 73 Basinghall Street, London, E.C.2. Tel.: METropolitan 8321.

Airtech Ltd. have formed an engineering division which is to offer a consultant design service for complete hydraulic and pneumatic systems and to manufacture a range of these components for industry at home and overseas.

Over 600 people have attended the series of fortnightly courses on Pegasus programming held at the Ferranti Computer Centre, 21 Portland Place, London, W.1.

Elliott-Automation Ltd. have purchased the entire share capital of Rotameter Manufacturing Co. Ltd., in consideration of the allotment of 269,000 ordinary shares of 5s. each in Elliott-Automation. Rotameter will remain under its former management and will continue to operate from its Croydon works.

Liquid Systems Ltd., Norwich Union House, Wellesley Road, Croydon, have signed an agreement with Schlegel Bros. Stuttgart, for the exclusive selling agency in the United Kingdom and Eire of their waste oil re-refining and waste oil filtering plants.

Whitworth Foundation awards for engineers to be offered for competition in 1958 are as follows: (a) Whitworth Fellowships (up to three), normally tenable for two years. They are valued at £500 a year and may be supplemented. (b) Up to six prizes of £50 each to unsuccessful competitors whose work deserves recognition. Details are obtainable from the Ministry of Education, Curzon Street, London, W.1.

An agreement has been made between Head Wrightson & Co. and the BAMAG Co. of Cologne, which enables Head Wrightson to offer designs of the Kaldo process to steel producers in the U.K. The new process involves blowing pure oxygen on to the surface of the metal revolving in a cylindrical furnace.

To celebrate the centenary of the founding of W. N. Baines & Co. Ltd., Rotherham—a company of the Bell's Asbestos & Engineering Group—a luncheon was given to all employees recently. Among those present were 18 members of the staff who had served the company for over 40 years.

The Iron and Steel Institute and the **Institute of Metals** have formed the Joint Powder Metallurgy Group. Addressing the inaugural meeting of the new body in London recently, its foundation chairman, Dr. I. Jenkins, chief metallurgist, G.E.C. Research Laboratories, expressed doubts as to whether the progress in powder metallurgy during the past few years had been "entirely satisfying". Fundamental research, in particular, was required urgently, he said, if the powder metallurgical industry was to keep pace with other industries in technological advance. The new group provided a forum which, he hoped, would encourage discussion between not only powder metallurgists themselves, but between them and other metallurgists in related fields. He looked forward to its work removing conservatism from the industry, yet at the same time preserving the competition element which was so stimulating. Among lines of investigation which should be pursued urgently were the study of metal surfaces, particularly at grain boundaries; a fundamental study of the effect of trace-activators; the nature of bonding of compounds and defects in bonding. During his address, Dr. Jenkins drew attention to the importance of chemical engineering processes in the extraction of metal powders "of considerable merit".

Among the plants visited by members of the Canadian Trade Mission who toured Britain recently was that of John Thompson Ltd., Wolverhampton. The visitors saw the production of heavy steel vessels for the Berkeley nuclear power station, Gloucestershire, and work in progress on vessels and process plant for the chemical and petroleum industries. Later they visited the group's pipework factory where processes in the production of stainless-steel pipework for the Berkeley contract were seen. At the Berkeley site members watched welding in progress on the 1000-ton reactor vessel, the lower domed portion of which is now in position and surrounded by thermal shielding.

Fisons horticultural fertiliser plant near Ipswich, remodelled at a cost of £265,000, was expected to be in production by the end of December. Mechanical equipment designed by the company's engineers and work-study experts has been installed to speed the production and packaging processes. A new administration block, staff canteen and laboratory are to be added during 1958—the centenary of the factory built on the site by Joseph Fison.

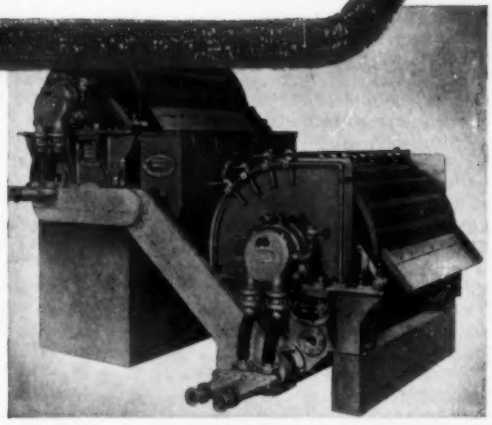
Constructors John Brown Ltd. have been awarded a £1¼-million contract for the construction of a natural-gas pipeline system in Lower Austria by Niogas, Niederosterreich Gasvertriebs A.G. The gas will be used mainly for industrial purposes, and the pipeline system will cover a total of 160 miles.

The reactor school at Harwell is to increase the number of courses to be held each year. Four standard courses will be held instead of three, each lasting sixteen weeks, and there will also be two courses for senior technical executives, each lasting nine days. The fee for a standard course is £250 and for a senior technical executives course £50. Applications have to be made three months in advance, and further details may be obtained from the Principal, Reactor School, A.E.R.E., Harwell, Didcot, Berks.

PAXMAN FILTERS

are used all over the world

Leading Dutch paper mills have installed Paxman filters for the washing and thickening of paper pulp. One of the most recent installations, the "Sove" plant at Arnhem—supplied in conjunction with the Cellulose Development Corporation Ltd.—includes five large Paxman filters, some of the deep submergence type, rubber-lined and with stainless steel parts.



Applications of Paxman filters in India include the filtration of paper pulp, the filtration of bichromates in a large industrial centre and the filtration of caustic lime sludge in a large paper mill near Calcutta.

Coal washeries recently supplied by Simon Carves of Stockport for collieries at Zonguldak and Catalagzi, Turkey, include 10 300 sq. ft. Paxman filters embodying cast-iron filter drums of the deep cell type, as used extensively in many British washeries.

WHILE filtration problems in various industries are necessarily individual, the Paxman Rotary Vacuum principle has proved markedly successful in all types of dewatering applications. Our Publication No. 1436 illustrates many specific examples of these which will certainly interest you. A copy awaits your request.

Paxman filters are widely used in the gold fields of South Africa for the filtration of cyanide slimes. Most of them have filtering areas of 700 sq. ft. A recently supplied filter deals with sludge containing calcium sulphate and ferrous hydroxide.

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Meetings of the Month

Institution of Chemical Engineers

December 17. *North Western Branch*: At Reynolds Hall, College of Science and Technology, Manchester. "Chemical engineering Aspects of Gas-solid Reactions", by Prof. K. G. Denbigh. **7 p.m.**

Society of Chemical Industry

December 18. *Corrosion Group*: At 14 Belgrave Square, London, S.W.1. "Teaching Corrosion Science"; "Existing Facilities", by L. W. Stubbs, and "Future Requirements", by T. P. Hoar. **2.30 p.m.**

January 14. *Chemical Engineering Group*: At Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. "New Developments in Inorganic Ion Exchangers", by J. M. Hutcheon and Dr. C. B. Amphlett. **5.30 p.m.**

The Physical Society

December 19 and 20. Second Conference on Solid State Physics: At Imperial College, London.

January 9. *Low Temperature Group*: At 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Annual General Meeting and "Problems and Prospects of Low Temperature Research", by Dr. K. Mendelssohn.

Institute of Metals

January 9. *Leeds Metallurgical Society*: At Lecture Room C, Chemistry Wing, The University, Leeds, 2. "Corrosion Problems and Water Treatment in Power Stations", by R. W. Wolforth. **7.15 p.m.**

January 14. *South Wales Local Section*: At the Department of Metallurgy, University College, Singleton Park, Swansea. "Electron Microscopy", by Dr. J. W. Menter. **6.30 p.m.**

Society of Instrument Technology

January 8. *South Yorkshire Section*: At The University, St. Georges Square, Sheffield, 1. "The History of Flow Measurement", by B. L. Thurley. **7 p.m.**

January 9. *Control Section*: At Manson House, Portland Place, London, W.1. "Design of Cascade Control Systems", by R. L. Day. **7 p.m.**

People in the News

Dr. T. G. Pickavance has been appointed Director of the High Energy Laboratory, Harwell, of the National Institute for Research in Nuclear Science. The laboratory, which is to be called the Rutherford High Energy Laboratory, is being built on a site adjacent to the A.E.R.E. At present Dr. Pickavance is in charge of the A.E.A. group responsible for the design and supervision of construction of a new accelerator for the Institute and he will continue to undertake that work.

Sir Miles Thomas, chairman of Monsanto, has been elected deputy chairman of the British Productivity Council.

Dr. R. Holroyd, deputy chairman of Imperial Chemical Industries Ltd., has been appointed Castner medallist, 1958, of the Society of Chemical Industry. The Society's Castner gold medal is awarded every two years to commemorate the work of Hamilton Young Castner, and is one of the Society's senior awards. Dr. Holroyd will receive his medal and deliver the Castner lecture, on an aspect of the petrochemical industry, early in 1958.

The Royal Society has elected the following members of council: **Sir Charles Dodds**, M.V.O., Courtauld professor of biochemistry, London; **Prof. G. Gee**, Sir Samuel Hall professor of chemistry, Manchester; **Prof. R. D. Haworth**, Firth professor of chemistry, Sheffield; **Prof. D. M. Newitt**, M.C., Courtauld professor of chemical engineering, Imperial College of Science and Technology; **Prof. R. E. Peierls**, C.B.E., professor of mathematical physics, Birmingham; and **Prof. L. Rosenhead**, C.B.E., professor of applied mathematics, Liverpool.

Mr. W. H. Apthorpe, managing director of Cambridge Instrument Co. Ltd., retired from executive duties at the end of 1957. He retains his seat on the board and continues to be available for special duties as deputy chairman. Mr. Apthorpe started his training with the company in 1900, and for seven years gained experience under the late Sir Horace Darwin. He resigned in 1907 to obtain further experience in association with Mr. Clarke-Fisher and the late R. W. Paul, and three years later was appointed assistant to the late Prof. Donnon at Liverpool. In 1914 he returned to the Cambridge Company to take charge of their testing department. He is succeeded by **Mr. H. C. Pritchard** who at present holds a senior position with Elliott Bros. In 1949 Mr. Pritchard was seconded by the R.A.E., for which he then worked, to the Australian Government as chief superintendent of the Woomera rocket range.

Mr. A. J. Somers, F.R.I.C., has retired after 36 years with Borax Consolidated Ltd. Since February, 1946, he has been a member of the board of the parent company. Originally engaged as a scientist, Mr. Somers spent many years between the wars promoting the industrial uses of borates and he became sales manager of the company in 1940.

Dr. H. G. Reid.

G. W. Innes.

Dr. H. G. Reid, who is at present general manager of the recently-announced Imperial Chemical Industries £100 million projected Severnside site which has recently been given approval by the Minister of Housing and Local Government, has been appointed president of Imperial Chemical Industries (New York) Ltd. with effect from January 1, 1958. Dr. Reid's place as

F. B. Rider

George C. Wells.

general manager is being taken by **Dr. H. S. Hirst,** of the company's Billingham Division in Co. Durham. Dr. Hirst was a member of the team who planned I.C.I.'s great Wilton works in North Yorkshire, and has recently been technical department manager of the Billingham Division. **Mr. J. D. Cousin,** until recently the secretary of the I.C.I. Salt Division in Cheshire, is now secretary of the Severnside project.

Mr. T. E. Houghton, an I.C.I. general chemicals division director and manager of that division's power department, has retired after more than 41 years' service with the company and its predecessors.

Mr. T. C. Fawcett, manager of the Northern Sales Region of I.C.I., has retired. **Mr. G. W. Innes,** personnel director of I.C.I.'s Alkali Division, has succeeded Mr. Fawcett as Northern regional manager.

Two new directors have recently been appointed to the board of the general chemicals division of I.C.I. **Mr. H. Shaw** has been appointed division technical director, and **Mr. G. E. Sutton,** who will also remain the division chief accountant, has been appointed division finance director.

Mr. C. J. Stairmand has been awarded the degree of Doctor of Science by the Senate of London University for his work on research into gas cleaning, atmospheric pollution and dedusting problems. Now a manager of I.C.I.'s chemical engineering research section, Billingham, Mr. Stairmand was awarded the Moulton Medal in 1951 by the Institution of Chemical Engineers for a paper on "The Design and Performance of Cyclone Separators". Before receiving his D.Sc. degree Mr. Stairmand submitted to the Faculty of Science 18 papers on research he has carried out over the past 25 years. The award of a D.Sc. is comparatively rare.

Mr. D. F. Ringe, formerly chief designer, has been appointed general manager and **Mr. K. D. Mulcaster,** formerly chief draughtsman, has been appointed to the position of chief designer of Vokes Ltd.

The appointment of **George C. Wells** as president of Union Carbide International Co., a division of Union Carbide Corporation, has been announced by **Morse G. Dial,** president of the Corporation. He succeeds **Mr. A. MacKenzie.**

Mr. F. B. Rider has been appointed sales manager of Thermocontrol Installations Co. Ltd. Mr. Rider was educated at Bancrofts School, Essex, and received his degree in 1940. He has served with De La Rue Ltd. and Matthew Hall Ltd.